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JOBS LOST, JOBS GAINED: WORKFORCE TRANSITIONS IN A TIME OF AUTOMATION

DECEMBER 2017

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MGI is led by three McKinsey & Company senior partners: Jacques Bughin, Jonathan Woetzel, and James Manyika, who also serves as the chairman of MGI. Michael Chui, Susan Lund, Anu Madgavkar, Sree Ramaswamy, and Jaana Remes are MGI partners, and Jan Mischke and Jeongmin Seong are MGI senior fellows.

Project teams are led by the MGI partners and a group of senior fellows, and include consultants from McKinsey offices around the world. These teams draw on McKinsey's global network of partners and industry and management experts. Advice and input to MGI research are provided by the MGI Council, members of which are also involved in MGI's research. MGI council members are drawn from around the world and from various sectors and include Andrés Cadena, Sandrine Devillard, Richard Dobbs, Tarek Elmasry, Katy George, Rajat Gupta, Eric Hazan, Eric Labaye, Acha Leke, Scott Nyquist, Gary Pinkus, Sven Smit, Oliver Tonby, and Eckart Windhagen. In addition, leading economists, including Nobel laureates, act as research advisers to MGI research.

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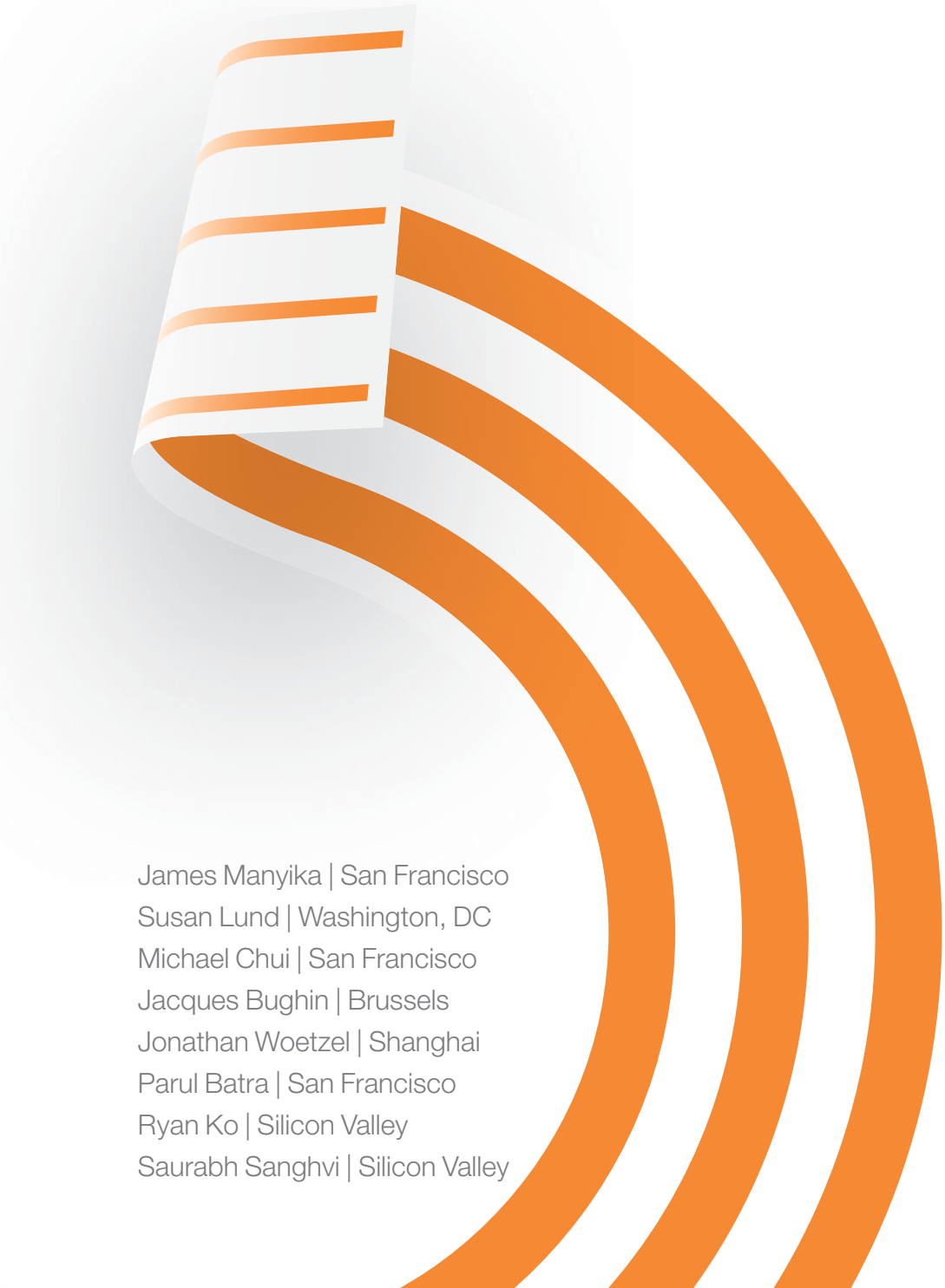

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PREFACE

Automation is not a new phenomenon, and fears about its transformation of the workplace and effects on employment date back centuries, even before the Industrial Revolution in the 18th and 19th centuries. In the 1960s, US President Lyndon Johnson empaneled a "National Commission on Technology, Automation, and Economic Progress." Among its conclusions was "the basic fact that technology destroys jobs, but not work."* Fast forward and rapid recent advances in automation technologies, including artificial intelligence, autonomous systems, and robotics are now raising the fears anew—and with new urgency. In our January 2017 report on automation, *A future that works: Automation, employment, and productivity*, we analyzed the automation potential of the global economy, the timelines over which the phenomenon could play out, and the powerful productivity boost that automation adoption could deliver.

This report goes a step further by examining both the potential labor market disruptions from automation and some potential sources of new labor demand that will create jobs. We develop scenarios that seek to address some of the questions most often raised in the public debate. Will there be enough work in the future to maintain full employment, and if so what will that work be? Which occupations will thrive, and which ones will wither? What are the potential implications for skills and wages as machines perform some or the tasks that humans now do?

The report is part of the McKinsey Global Institute's research program on the future of work, and is by no means the final word on this topic. The technology continues to evolve, as will our collective understanding of the economic implications. Indeed, we highlight some of the limitations of our analysis and scenarios, and areas for further research. The report builds on our previous research on labor markets, incomes, skills, and the expanding range of models of work, including the gig economy, as well as the potential impacts on the global economy of digitization, automation, robotics, and artificial intelligence.

The research was led by James Manyika, chairman and director of the McKinsey Global Institute and McKinsey senior partner based in San Francisco; Susan Lund, an MGI partner based in Washington, DC; Michael Chui, an MGI partner in San Francisco; Jacques Bughin, MGI director and McKinsey senior partner based in Brussels; and Jonathan Woetzel, MGI director and McKinsey senior partner in Shanghai. Parul Batra, Ryan Ko, and Saurabh Sanghvi headed the research team at different times over the course of the project. The team comprised Julian Albert, Gurneet Singh Dandona, Nicholas Fletcher, Darien Lee, Nik Nayar, Sonia Vora, and Rachel Wong.

We are deeply grateful to our academic advisers, who challenged our thinking and provided valuable feedback and guidance throughout the research. We thank Richard N. Cooper, Maurits C. Boas Professor of International Economics at Harvard University; Sir Christopher Pissarides, Nobel laureate and Regius Professor of Economics at the London School of Economics; Michael Spence, Nobel laureate and William R. Berkley Professor in Economics and Business at the NYU Stern School of Business; and Laura Tyson, Professor of Business Administration and Economics at the Haas School of Business, University of California, Berkeley.

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* *Technology and the American economy: Report of the National Commission on Technology, Automation, and Economic Progress*, US Department of Health, Education, and Welfare, February 1966.

Colleagues from around the world offered valuable insights into various aspects of our research. We thank Jens Riis Anderson, Jake Bryant, Richard Dobbs, Rajat Gupta, Kimberly Henderson, Tasuku Kuwabara, Meredith Lapointe, Jan Mischke, Anu Madgavkar, Deepa Mahajan, Mona Mourshed, Chandrika Rajagopalan, Jaana Remes, Jimmy Sarakatsannis, Katharina Schumacher, Jeongmin Seong, Bob Sternfels, and Eckart Windhagen.

We are also grateful to the following McKinsey colleagues who provided technical advice and analytical support: Peter Aagaard, Jonathan Ablett, Rohit Agarwal, Tarun Agarwal, Moinak Bagchi, Drew Baker, Sergio Balcazar, Tim Beacom, Shannon Bouton, Leon Chen, Debadrita Dhara, Eduardo Doryan, Alan FitzGerald, Isabelle Fisher, Sarah Forman, Boyan Gerasimov, Enrique Gonzalez, Nicolas Grosman, Jose Mora Guerrero, Shishir Gupta, Fernanda Hernandez, Shumi Jain, Frederik Jensen, Karen Jones, Priyanka Kamra, Arpit Kaur, Mekala Krishnan, Priyanka Kumar, Krzysztof Kwiatkowski, Alison Lai, Freya Li, Mike Munroe, Jesse Noffsinger, Emilio Noriega, Erik Rong, Martin Schultz-Nielsen, Narasimhan Seshadri, Raman Sharma, Vivien Singer, Rachel Valentino, Charlotte van Dixhoorn, Jerry van Houten, Mike Wang, Wendy Wong, Hank Yang, and Desmond Zheng.

This report was edited and produced by MGI senior editor Peter Gumbel, editorial production manager Julie Philpot, senior graphic designers Marisa Carder, Margo Shimasaki, and Patrick White, and data visualization editor Richard Johnson. Rebeca Robboy, MGI director of external communications, managed dissemination and publicity, while digital editor Lauren Meling provided support for online publication and social media. We thank Deadra Henderson, MGI's manager of personnel and administration, for her support.

This report contributes to MGI's mission to help business and policy leaders understand the forces transforming the global economy, identify strategic locations, and prepare for the next wave of growth. As with all MGI research, this work is independent and has not been commissioned or sponsored in any way by any business, government, or other institution. While we are grateful for all the input we have received, the report and views expressed here are ours alone. We welcome your comments on this research at **MGI@mckinsey.com**.

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December 2017

On Fifth Avenue, New York
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CONTENTS

HIGHLIGHTS

History's lessons

Middle-wage conundrum

The retraining challenge

In brief

Summary of findings
Page 1

1. Jobs lost, jobs changed: Impact of automation on work
Page 23

2. Lessons from history on technology and employment
Page 33

3. Jobs gained: Scenarios for employment growth
Page 55

4. Implications for skills and wages
Page 77

The future of work by country
Page 91

China	92
Germany	94
India	96
Japan	98
Mexico	100
United States	102

5. Managing the workforce transitions
Page 105

6. Priorities for government, business, and individuals
Page 123

Technical appendix
Page 131

Bibliography
Page 143

IN BRIEF

JOBS LOST, JOBS GAINED: WORKFORCE TRANSITIONS IN A TIME OF AUTOMATION

In our latest research on automation, we examine work that can be automated through 2030 and jobs that may be created in the same period. We draw from lessons from history and develop various scenarios for the future. While it is hard to predict how all this will play out, our research provides some insights into the likely workforce transitions that should be expected and their implications. Our key findings:

- Automation technologies including artificial intelligence and robotics will generate significant benefits for users, businesses, and economies, lifting productivity and economic growth. The extent to which these technologies displace workers will depend on the pace of their development and adoption, economic growth, and growth in demand for work. Even as it causes declines in some occupations, automation will change many more—60 percent of occupations have at least 30 percent of constituent work activities that could be automated. It will also create new occupations that do not exist today, much as technologies of the past have done.
- While about half of all work activities globally have the technical potential to be automated by adapting currently demonstrated technologies, the proportion of work actually displaced by 2030 will likely be lower, because of technical, economic, and social factors that affect adoption. Our scenarios across 46 countries suggest that between almost zero and one-third of work activities could be displaced by 2030, with a midpoint of 15 percent. The proportion varies widely across countries, with advanced economies more affected by automation than developing ones, reflecting higher wage rates and thus economic incentives to automate.
- Even with automation, the demand for work and workers could increase as economies grow, partly fueled by productivity growth enabled by technological progress. Rising incomes and consumption especially in developing countries, increasing health care for aging societies, investment in infrastructure and energy, and other trends will create demand for work that could help offset the displacement of workers. Additional investments such as in infrastructure and construction, beneficial in their own right, could be needed to reduce the risk of job shortages in some advanced economies.
- Even if there is enough work to ensure full employment by 2030, major transitions lie ahead that could match or even exceed the scale of historical shifts out of agriculture and manufacturing. Our scenarios suggest that by 2030, 75 million to 375 million workers (3 to 14 percent of the global workforce) will need to switch occupational categories. Moreover, all workers will need to adapt, as their occupations evolve alongside increasingly capable machines. Some of that adaptation will require higher educational attainment, or spending more time on activities that require social and emotional skills, creativity, high-level cognitive capabilities and other skills relatively hard to automate.
- Income polarization could continue in the United States and other advanced economies, where demand for high-wage occupations may grow the most while middle-wage occupations decline—assuming current wage structures persist. Increased investment and productivity growth from automation could spur enough growth to ensure full employment, but only if most displaced workers find new work within one year. If reemployment is slow, frictional unemployment will likely rise in the short-term and wages could face downward pressure. These wage trends are not universal: in China and other emerging economies, middle-wage occupations such as service and construction jobs will likely see the most net job growth, boosting the emerging middle class.
- To achieve good outcomes, policy makers and business leaders will need to embrace automation's benefits and, at the same time, address the worker transitions brought about by these technologies. Ensuring robust demand growth and economic dynamism is a priority: history shows that economies that are not expanding do not generate job growth. Midcareer job training will be essential, as will enhancing labor market dynamism and enabling worker redeployment. These changes will challenge current educational and workforce training models, as well as business approaches to skill-building. Another priority is rethinking and strengthening transition and income support for workers caught in the cross-currents of automation.

JOBS LOST GAINED CHANGED

Automation will bring big shifts to the world of work, as AI and robotics change or replace some jobs, while others are created. Millions of people worldwide may need to switch occupations and upgrade skills.

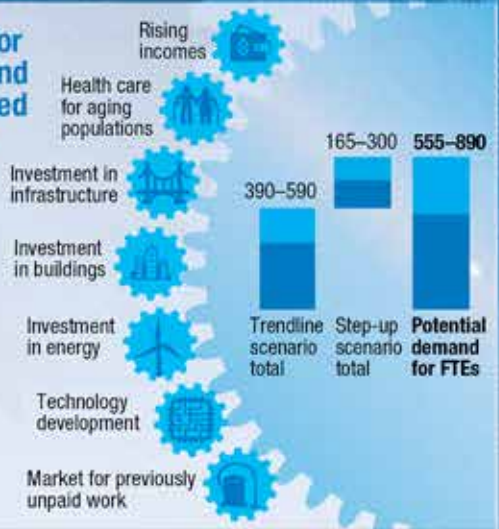
Scenarios for automation adoption, 2016–30

Under midpoint scenario, % of work hours with potential to be automated

Workers displaced under midpoint automation scenario: **400M**

Scenarios for labor demand from selected catalysts, 2016–30

Million FTEs, ranged low–high



Jobs of the future: some occupations will grow, others will decline, and new ones we cannot envision will be created

Workforce transitions

Our scenarios for automation and labor demand highlight challenges for workers

SWITCHING OCCUPATIONS...

75M–375M

Number of people who may need to switch occupational categories by 2030, under our midpoint to rapid automation adoption scenarios

...DEMANDING NEW SKILLS...

...CHANGING EDUCATIONAL REQUIREMENTS

	Advanced	Emerging
Secondary or less	▽	▲
Associate	=	▲
College and advanced	▲	▲

Priorities for policy makers and business leaders

ECONOMIC GROWTH
Ensuring robust demand growth and economic dynamism; economies that are not expanding don't create jobs

SKILLS UPGRADE
Upgrading workforce skills, especially retraining midcareer workers, as people work more with machines

FLUID LABOR MARKET
The shifting occupational mix will require more fluid labor markets, greater mobility, and better job matching

TRANSITION SUPPORT
Adapting income and transition support to help workers and enable those displaced to find new employment

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Help wanted, Beverly Hills, California
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SUMMARY OF FINDINGS

The technology-driven world in which we live is a world filled with promise but also challenges. Cars that drive themselves, machines that read X-rays, and algorithms that respond to customer service inquiries are all manifestations of powerful new forms of automation. Yet even as these technologies increase productivity and improve our lives, their use will substitute for some work activities humans currently perform—a development that has sparked much public concern.

This research builds on MGI's January 2017 report on automation and its impact on work activities.[1] We assess the number and types of jobs that might be created under different scenarios through 2030, and compare that to work that could be displaced by automation.[2] The results reveal a rich mosaic of potential shifts in occupations in the years ahead, with important implications for workforce skills and wages. The analysis covers 46 countries that comprise almost 90 percent of global GDP. We focus on six countries that span income levels (China, Germany, India, Japan, Mexico, and the United States). For each, we modeled the potential net employment changes for more than 800 occupations, based on different scenarios for the pace of automation adoption and for future labor demand. The intent of this research is not to forecast. Rather, we present a set of scenarios (necessarily incomplete) to serve as a guide, as we anticipate and prepare for the future of work. This research is by no means the final word on this topic; ongoing research is required. Indeed, in Box E2 at the end of this summary, we highlight some of the potential limitations of the research presented in this report.

Our findings suggest that several trends that may serve as catalysts of future labor demand could create demand for millions of jobs by 2030. These trends include caring for others in aging societies, raising energy efficiency and meeting climate challenges, producing goods and services for the expanding consuming class, especially in developing countries, not to mention the investment in technology, infrastructure, and buildings needed in all countries. Taken from another angle, we also find that a growing and dynamic economy—in part fueled by technology itself and its contributions to productivity—would create jobs. These jobs would result from growth in current occupations due to demand and the creation of new types of occupations that may not have existed before, as has happened historically. This job growth (jobs gained) could more than offset the jobs lost to automation. None of this will happen by itself—it will require businesses and governments to seize opportunities to boost job creation and for labor markets to function well. The workforce transitions ahead will be enormous. We estimate that as many as 375 million workers globally (14 percent of the global workforce) will likely need to transition to new occupational categories and learn new skills, in the event of rapid automation adoption. If their transition to new jobs is slow, unemployment could rise and dampen wage growth.

Indeed, while this report is titled *Jobs lost, jobs gained*, it could have been, *Jobs lost, jobs changed, jobs gained*; in many ways a big part of this story is about how more occupations will change than will be lost as machines affect portions of occupations and people increasingly work alongside them. Societal choices will determine whether all three of these

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1 *A future that works: Automation, employment, and productivity*, McKinsey Global Institute, January 2017.

2 We use the term "jobs" as shorthand for full-time equivalent workers (FTEs), and apply it to both work displaced by automation and to new work created by future labor demand. In reality, the number of people working is larger than the number of FTEs, as some people work part-time. Our analysis of FTEs covers both employees within firms as well as independent contractors and freelancers.

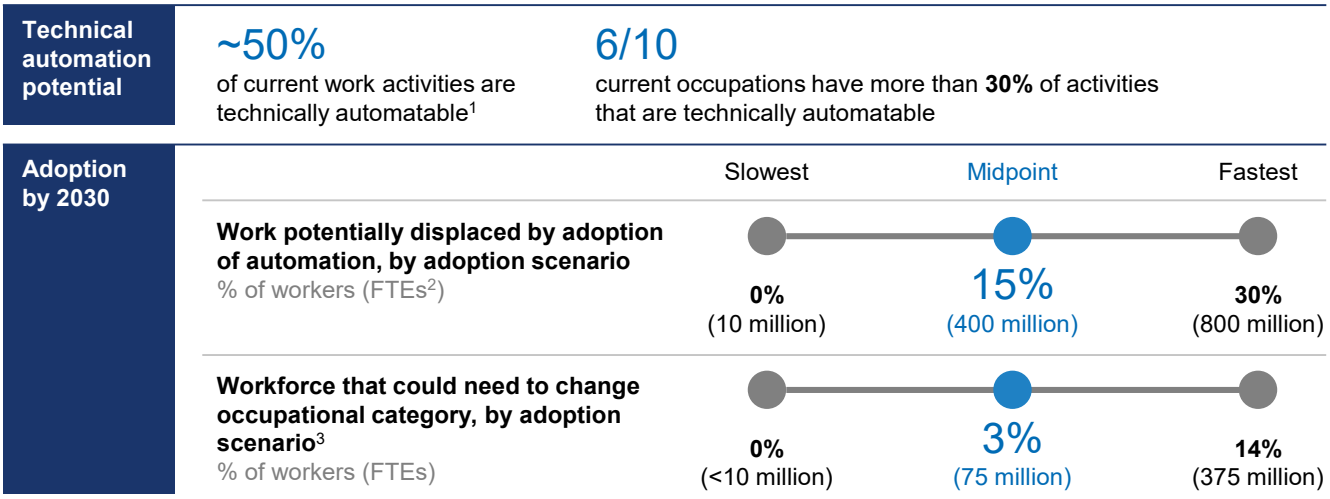
coming workforce transitions are smooth, or whether unemployment and income inequality rise. History shows numerous examples of countries that have successfully ridden the wave of technological change by investing in their workforce and adapting policies, institutions, and business models to the new era. It is our hope that this report prompts leaders in that direction once again.

AUTOMATION COULD DISPLACE A SIGNIFICANT SHARE OF WORK GLOBALLY TO 2030; 15 PERCENT IS THE MIDPOINT OF OUR SCENARIO RANGE

In our prior report on automation, we found that about half the activities people are paid to do globally could theoretically be automated using currently demonstrated technologies.[3] Very few occupations—less than 5 percent—consist entirely of activities that can be fully automated. However, in about 60 percent of occupations, at least one-third of the constituent activities could be automated, implying substantial workplace transformations and changes for all workers. All this is based on our assessments of current technological capability—an ever evolving frontier (Exhibit E1).

Exhibit E1

Global workforce numbers at a glance



1 By adapting currently demonstrated technologies.
2 Full-time equivalents.
3 In trendline labor-demand scenario.

SOURCE: McKinsey Global Institute analysis

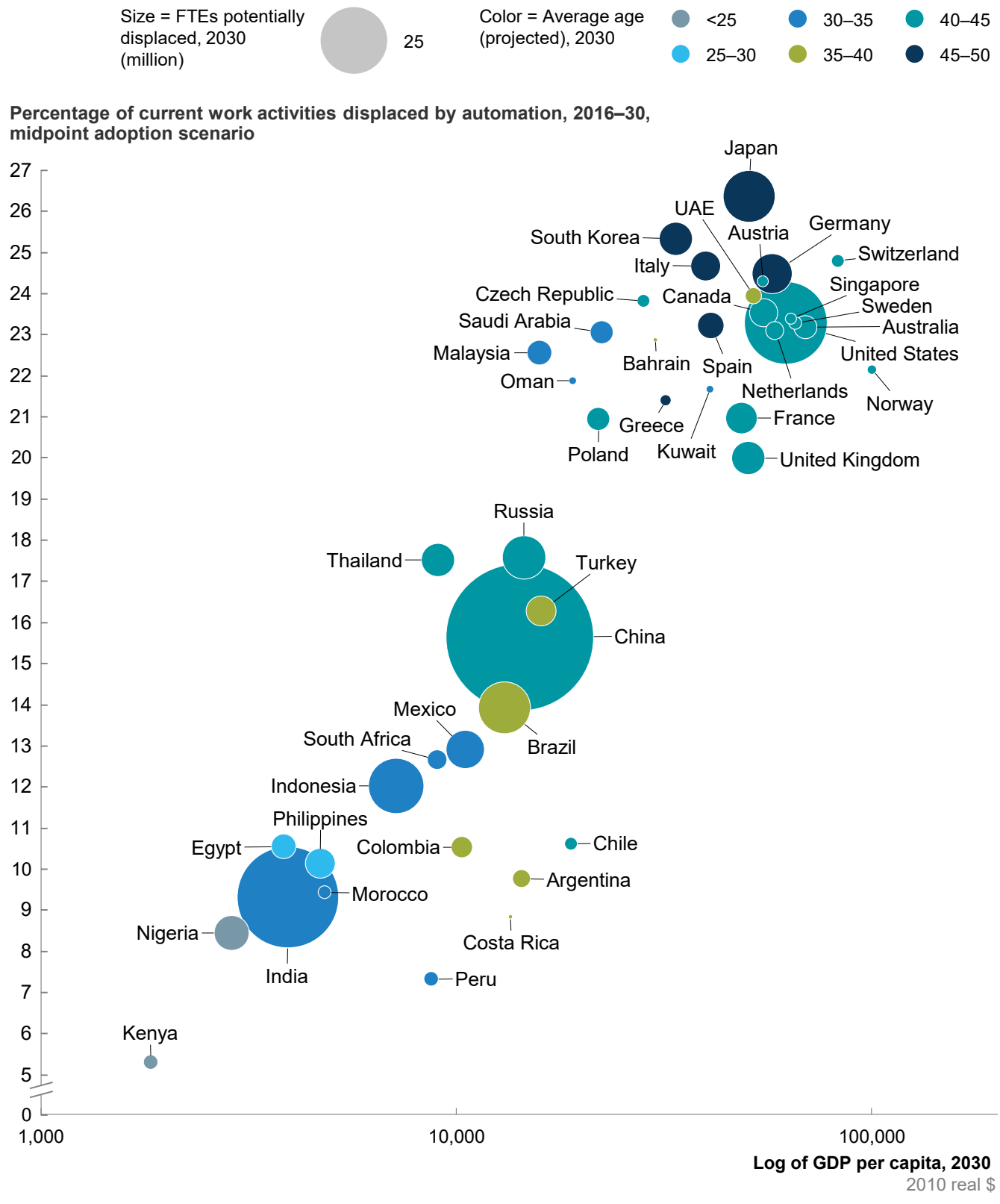
While technical feasibility of automation is important, it is not the only factor that will influence the pace and extent of automation adoption. Other factors include the cost of developing and deploying automation solutions for specific uses in the workplace, the labor market dynamics (including quality and quantity of labor and associated wages), the benefits of automation beyond labor substitution, and regulatory and social acceptance. Taking into account these factors, our new research estimates that between almost zero and 30 percent of the hours worked globally could be automated by 2030, depending on the speed of adoption. In this report we mainly use the midpoint of our scenario range, which is 15 percent of current activities automated. Results differ significantly by country, reflecting the mix of activities currently performed by workers and prevailing wage rates. They range

[3] Our definition of automation includes robotics (machines that perform physical activities) and artificial intelligence (software algorithms that perform calculations and cognitive activities). Companies may adopt these technologies for reasons other than labor cost savings, such as improved quality, efficiency, or scale, although worker displacement could still be a consequence. A glossary of automation technologies and techniques is in the technical appendix.

from 9 percent in India to 26 percent in Japan in the midpoint adoption rate scenario (Exhibit E2). This is on par with the scale of the great employment shifts of the past, such as out of agriculture or manufacturing (Box E1, "The historical evidence on technology and employment is reassuring").

Exhibit E2

Impact of automation varies by a country's income level, demographics, and industry structure



SOURCE: World Bank; Oxford Economics; McKinsey Global Institute analysis

Box E1. The historical evidence on technology and employment is reassuring

Technology adoption can and often does cause significant short-term labor displacement, but history shows that, in the longer run, it creates a multitude of new jobs and unleashes demand for existing ones, more than offsetting the number of jobs it destroys even as it raises labor productivity (Exhibit E3).[1] An examination of the historical record highlights several lessons:

- All advanced economies have experienced profound sectoral shifts in employment, first out of agriculture and more recently manufacturing, even as overall employment grew. In the United States, the agricultural share of total employment declined from 60 percent in 1850 to less than 5 percent by 1970, while manufacturing fell from 26 percent of total US employment in 1960 to below 10 percent today. Other countries have experienced even faster declines: one-third of China's workforce moved out of agriculture between 1990 and 2015.
- Such shifts can have painful consequences for some workers. During the Industrial Revolution in England, average real wages stagnated for decades, even as productivity rose.[2] Eventually, wage growth caught up to and then surpassed productivity growth. But the transition period was difficult for individual workers, and eased only after substantial policy reforms.
- New technologies have spurred the creation of many more jobs than they destroyed, and some of the new jobs are in occupations that cannot be envisioned at the outset; one study found that 0.56 percent of new jobs in the United States each year are in new occupations.[3] Most jobs created by technology are outside the technology-producing sector itself. We estimate that the introduction of the personal computer, for instance, has enabled the creation of 15.8 million net new jobs in the United States since 1980, even after accounting for jobs displaced. About 90 percent of these are in occupations that use the PC in other industries, such as call center representatives, financial analysts, and inventory managers.
- Robust aggregate demand and economic growth are essential for job creation. New technologies have raised productivity growth, enabling firms to lower prices for consumers, pay higher wages, or distribute profits to shareholders. This stimulates demand across the economy, boosting job creation.[4]
- Rising productivity is usually accompanied by employment growth, because it raises incomes which are then spent, creating demand for goods and services across the economy. When there has been a tradeoff between employment growth and labor productivity growth, it has been short-lived. In the United States, for example, our analysis shows that employment and productivity both grew in 95 percent of rolling three-year periods and 100 percent of rolling 10-year periods since 1960.
- Over the long term, productivity growth enabled by technology has reduced the average hours worked per week and allowed people to enjoy more leisure time.[5] Across advanced economies, the length of the average work-week has fallen by nearly 50 percent since the early 1900s, reflecting shorter working hours, more paid days off for personal time and vacations, and the recent rise of part-time work. The growth in leisure has created demand for new industries, from golf to video games to home improvement.

Although the historical record is largely reassuring, some people worry that automation today will be more disruptive than in the past. Technology experts and economists are debating whether "this time, things are different" (and we examine that debate starting on page 48 of this report). Our current view is that the answer depends on the time horizon considered (decades or centuries) and on the pace of future technological progress and adoption. On many dimensions, we find similarities between the scope and effects of automation today compared to earlier waves of technology disruption, going back to the Industrial

1 David H. Autor, "Why are there still so many jobs? The history and future of workplace automation," *Journal of Economic Perspectives*, volume 29, number 3, summer 2015.

2 Robert C. Allen, "Engels' pause: Technical change, capital accumulation, and inequality in the British industrial revolution," *Explorations in Economic History*, volume 46, number 4, October 2009.

3 This implies that 18 percent of the workforce today is employed in an occupation that essentially did not exist in 1980. Jeffrey Lin, "Technological adaptation, cities, and new work," *Review of Economics and Statistics*, volume 93, number 2, May 2011.

4 David Autor and Anna Salomons, "Does productivity growth threaten employment?" Working paper prepared for ECB Forum on Central Banking, June 2017.

5 For instance, see Mark Aguiar and Erik Hurst, "Measuring trends in leisure: The allocation of time over five decades," *The Quarterly Journal of Economics*, volume 122, issue 3, August 2007.

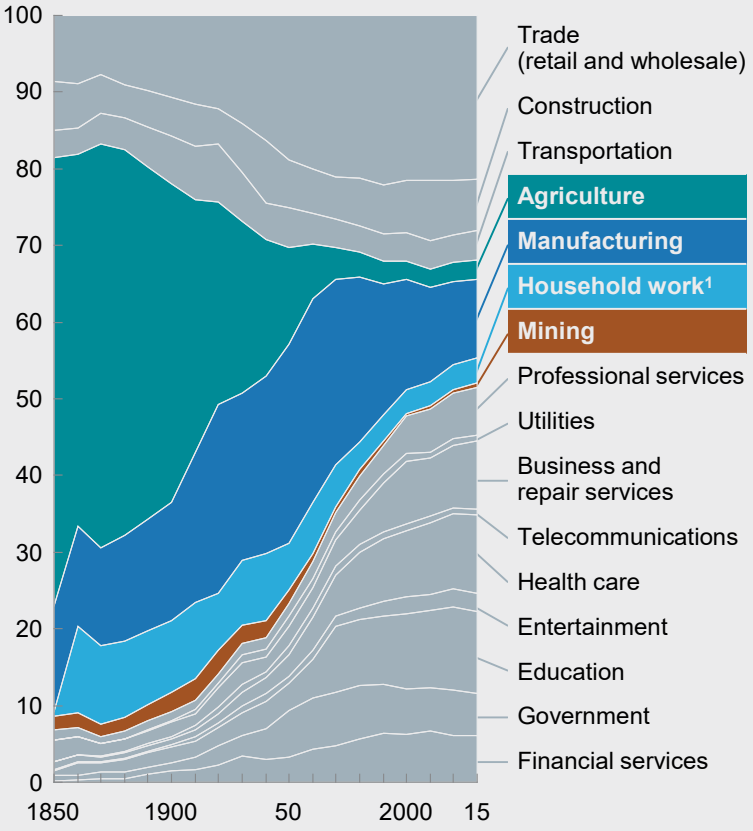
Revolution. However, automation going forward might prove to be more disruptive than in recent decades—and on par with the most rapid changes in the past—in two ways. First, if technological advances continue apace and are adopted rapidly, the rate of worker displacement could be faster. Secondly, if many sectors adopt automation simultaneously, the percentage of the workforce affected by it could be higher.

Exhibit E3

History shows that technology has created large employment and sector shifts, but also creates new jobs

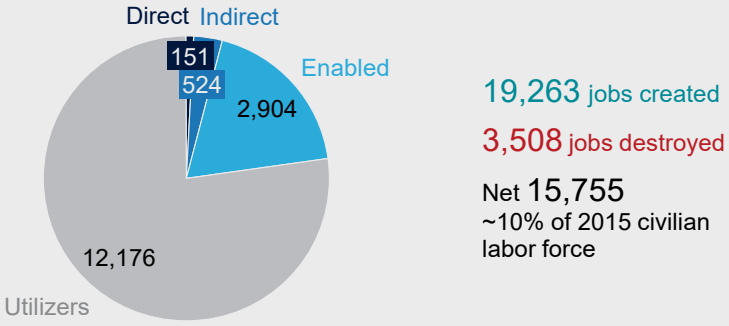
Large-scale sector employment declines have been countered by growth of other sectors that have absorbed workers

Share of total employment by sector in the United States, 1850–2015



Technology creates more jobs than it destroys over time, mainly outside the industry itself

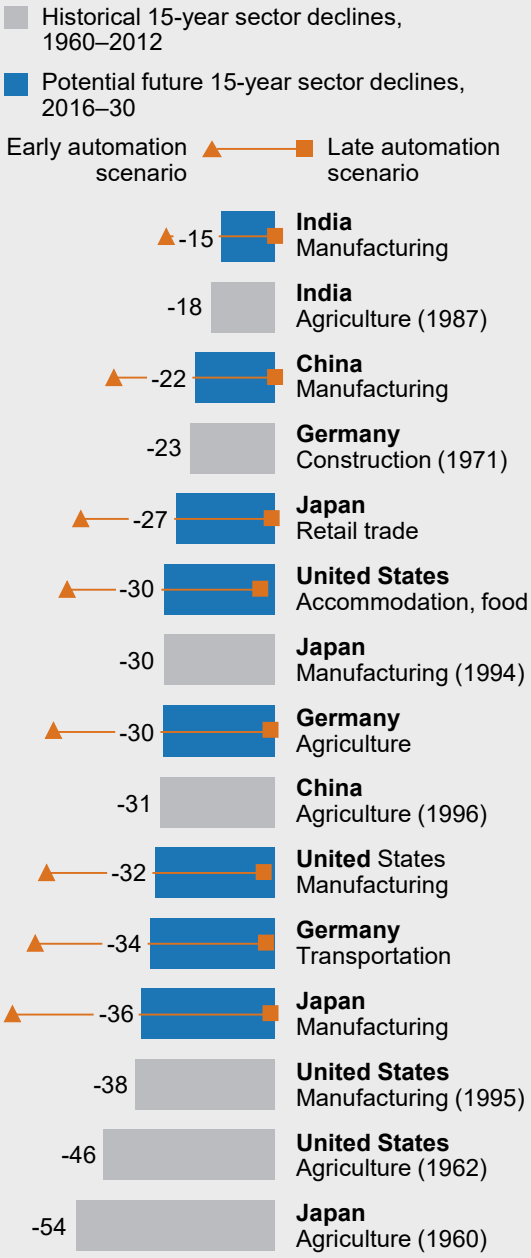
Example: Personal computers (total US jobs created, thousand)



Selected examples of large sector employment declines, past and future

% decline in sector employment

% of FTEs



1 Increase from 1850 to 1860 in employment share of household work primarily due to changes in how unpaid labor (slavery) was tracked.
NOTE: Numbers may not sum due to rounding.

SOURCE: IPUMS USA 2017; US Bureau of Labor Statistics; Groningen Growth and Development Centre 10-Sector Database; Moody's; IMPLAN; US Bureau of Labor Statistics; FRED; McKinsey Global Institute analysis

The potential impact of automation on employment varies by occupation and sector. Activities most susceptible to automation include physical ones in predictable environments, such as operating machinery and preparing fast food. Collecting and processing data are two other categories of activity that can increasingly be done better and faster with machines. This could displace large amounts of labor, for instance in mortgage origination, paralegal work, accounting, and back-office transaction processing. It is important to note, however, that even when some tasks are automated, employment in those occupations may not decline, but rather workers may perform new tasks. In addition, employment in occupations may also grow, if the overall demand for that occupation grows enough to overwhelm the rates of automation.

Automation will have a lesser effect on jobs that involve managing people, applying expertise, and those involving social interactions, where machines are unable to match human performance for now. Jobs in unpredictable environments—occupations such as gardeners, plumbers, or providers of child- and elder-care—will also generally see less automation by 2030, because they are difficult to automate technically and often command relatively lower wages, which makes automation a less attractive business proposition.

RISING INCOMES, INVESTMENTS IN INFRASTRUCTURE AND ENERGY, AND OTHER CATALYSTS COULD POTENTIALLY CREATE MILLIONS OF NEW JOBS

Up to **130M** new jobs in health care from aging and rising incomes by 2030

While automation's displacement of labor has been visible for many years, it is more difficult to envision all the new jobs that will be created. Many of these new jobs are created indirectly and spread across different sectors and geographies.

In this report, we model some potential sources of new labor demand that may spur job creation to 2030, even net of automation. We consider two scenarios, a "trendline" scenario based on current spending and investment trends observed across countries, and a "step-up" scenario that assumes additional investments in some areas. We calculate jobs (full-time equivalents) that could be created both directly and indirectly for more than 800 existing occupations. We do not consider the dynamic interactions between trends or across the economy (Exhibit E4). The results are not precise forecasts of future job growth, but rather are suggestive of where jobs of the future may be.

For three trends, we model only a trendline scenario. They are:

- **Rising incomes and consumption, especially in emerging economies.** Previous MGI research has estimated that 1 billion more people will enter the consuming class by 2025.[4] Using external macroeconomic forecasts, we estimate that global consumption could grow by $23 trillion between 2015 and 2030, and most of this will come from the expanding consuming classes in emerging economies. As incomes rise, consumers spend more on all categories. But their spending patterns also shift, creating more jobs in areas such as consumer durables, leisure activities, financial and telecommunication services, housing, health care, and education. The effects of these new consumers will be felt not just in the countries where the income is generated, but also in economies that export to those countries.[5] Globally, we estimate that 300 million to 365 million new jobs could be created from the impact of rising incomes.

- **Aging populations.** By 2030, there will be at least 300 million more people aged 65 years and above than there were in 2014. As people age, their spending patterns

[4] We define consuming classes or consumers as individuals with an annual income of more than $3,600, or $10 per day, at purchasing power parity, using constant 2005 PPP dollars. *Urban world: Cities and the rise of the consuming class*, McKinsey Global Institute, June 2012.

[5] We assume that current patterns of global trade continue, at the same level relative to GDP as today. As a result, advanced economies also benefit from rising incomes in developing countries. The United States, for example, could gain up to 3 percent of net new jobs from rising incomes by 2030 from net exports. In Germany's case, that figure could be more than 40 percent.

shift, with a pronounced increase in spending on health care and other personal services. This will create significant demand for a range of occupations, including doctors, nurses, and health technicians, but also home health aides, personal care aides and nursing assistants in many countries, even as it reduces demand for pediatricians and primary-school teachers. Globally, we estimate heath care and related jobs from aging and rising incomes could grow by 80 million to 130 million by 2030.[6]

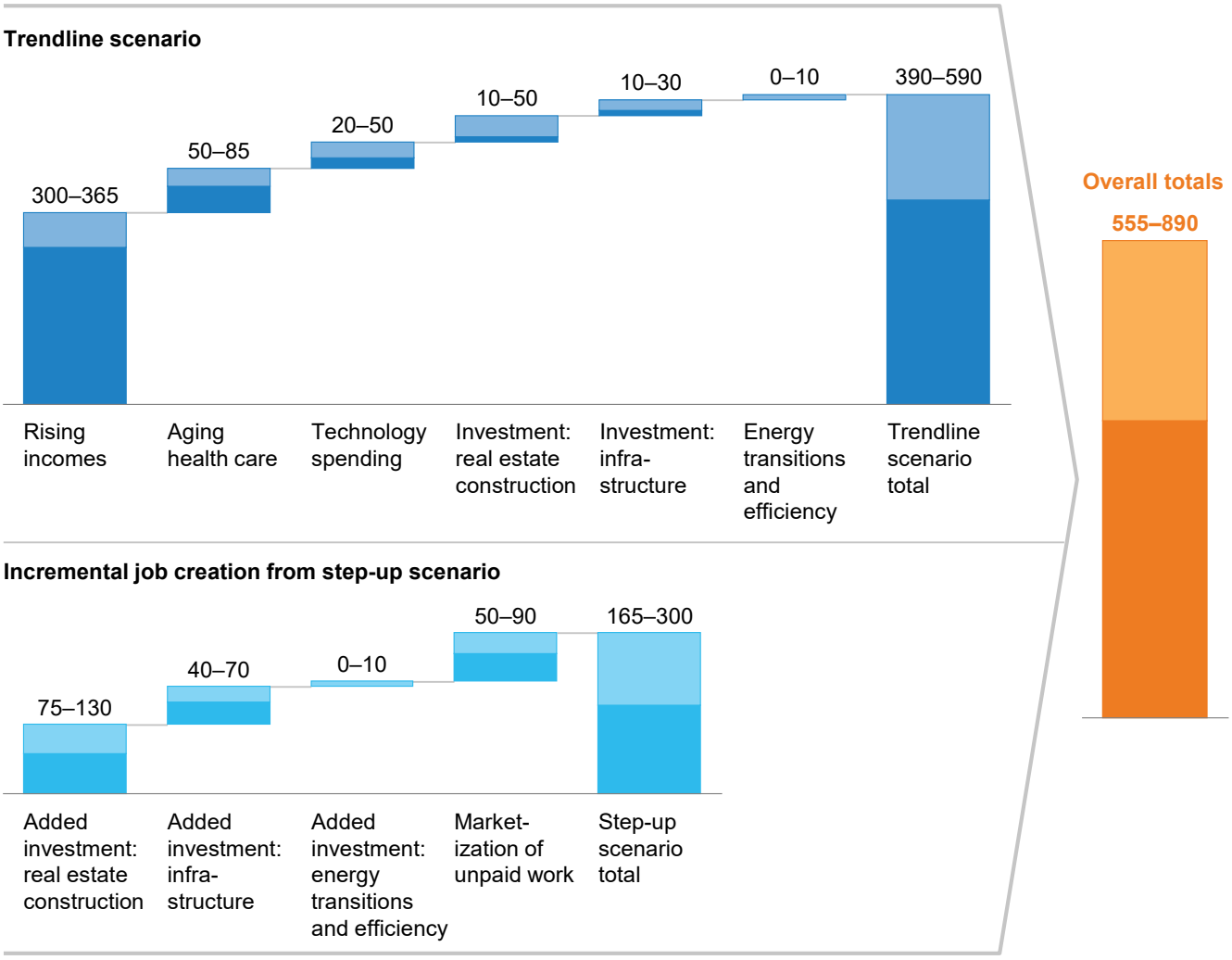
50M
new technology jobs by 2030

- **Development and deployment of technology.** Jobs related to developing and deploying new technologies may also grow. These jobs include computer scientists, engineers, and IT administrators. Overall spending on technology could increase by more than 50 percent between 2015 and 2030. About half would be on information technology services, both in-house IT workers within companies and external or outsourced tech consulting jobs. The number of people employed in these occupations is small compared to those in health care or construction, but they are high-wage occupations. By 2030, we estimate this trend could create 20 to 50 million jobs globally.

Exhibit E4

Rising consumer incomes are the largest source of job creation among our seven catalysts

Potential jobs created from seven catalysts of labor demand, midpoint automation, 2016–30[1]
Million FTEs, ranged low–high



1 Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: McKinsey Global Institute analysis

6 We net out the effect of fewer health-care jobs related to children in this trend.

For three other trends, we model both a trendline scenario and a step-up scenario; the latter is based on explicit choices that could be made by governments, business leaders, and individuals to create additional jobs.

- **Investment in infrastructure and buildings.** Infrastructure and buildings are two areas of historic underspending that may create significant additional labor demand if action is taken to bridge infrastructure gaps and overcome housing shortages. MGI has estimated that the world needs to invest about 3.8 percent of GDP annually, or an average of $3.3 trillion per year to fill infrastructure gaps, compared with $2.5 trillion currently.[7] This includes both developing countries that are urbanizing and industrializing, and advanced economies that have underinvested in maintaining their infrastructure and buildings. Rising incomes also create demand for more and higher quality buildings. Both factors could create new demand, mainly in the construction sector, for up to 80 million jobs in the trendline scenario and, in some cases, potentially up to 200 million globally in the step-up scenario.[8] These jobs include architects, engineers, carpenters and other skilled tradespeople, as well as construction workers, machinery operators and other jobs with lower skill requirements.

- **Investments in renewable energy, energy efficiency, and climate adaptation.** Investments in renewable energy, such as wind and solar, energy efficiency technologies, and adaptation and mitigation of climate change may create new demand for workers in a range of occupations, including in manufacturing, construction, and installation. In our trendline scenario, we model future job growth based on already-announced policy intentions for energy efficiency and the required investment to meet these goals.[9] For a step-up scenario, we use more ambitious targets that countries will need to get closer to meeting commitments to the Paris climate accord.[10] These investments could create up to ten million new jobs in the trendline scenario, and up to ten million additional jobs globally in the step-up scenario.

20M
potential new jobs from energy investments in our step-up scenario

- **"Marketization" of previously unpaid domestic work.** The last trend we consider is the potential to pay for services that substitute for currently unpaid and primarily domestic work—including cooking, childcare, and cleaning. This so-called marketization of previously unpaid work is already prevalent in advanced economies, and rising female labor force participation worldwide could accelerate the trend. About 75 percent of the world's total unpaid care is undertaken by women and amounts to as much as $10 trillion of output per year, roughly equivalent to 13 percent of global GDP.[11] Individual decisions within the household to use paid services or government investment to provide universal childcare and pre-school could fuel this development. We consider this in the step-up scenario only, as its magnitude and timing is unclear. But we estimate that this shift could marketize 50 million to 90 million unpaid jobs globally, mainly in occupations such as childcare, early childhood education, cleaning, cooking, and gardening.

7 *Bridging global infrastructure gaps*, McKinsey Global Institute, June 2016.

8 In the step-up scenario, we assume higher levels of run-rate infrastructure investment after countries have closed their respective infrastructure gap. We also assume that, at minimum, countries reach levels of commercial and residential real estate investment comparable to those in the United States.

9 Energy efficiency data from *World energy outlook 2016*, International Energy Agency, November 2016. See also *Beyond the supercycle: How technology is reshaping resources*, McKinsey Global Institute, February 2017.

10 While the United States has announced that it will withdraw from the Paris Agreement, other signatory countries have said they will continue to meet agreed emission reduction targets.

11 *The power of parity: How advancing women's equality can add $12 trillion to global growth*, McKinsey Global Institute, September 2015.

UP TO 375 MILLION PEOPLE MAY NEED TO SWITCH OCCUPATIONAL CATEGORIES, WITH THE HIGHEST SHARE IN ADVANCED ECONOMIES

When we look at the net changes in job growth and decline from the trends described above compared with the work that can be automated, a mosaic of shifts in occupations and job categories emerges (Exhibit E5).

Across all countries, the categories with the highest percentage job growth net of automation include health-care providers; professionals such as engineers, scientists, accountants, and analysts; IT professionals and other technology specialists; managers and executives, whose work cannot easily be replaced by machines; educators, especially in emerging economies with young populations; and "creatives," a small but growing category of artists, performers, and entertainers who will be in demand as rising incomes create more demand for leisure and recreation. Builders and related professions will also grow, particularly in the step-up scenario that involves higher investment in infrastructure and buildings. Manual and service jobs in unpredictable environments will also grow, such as home health aides and gardeners.

Advanced economies may also see employment declines in occupations that are most susceptible to automation. These include office support occupations, such as record clerks, office assistants, and finance and accounting; some customer interaction jobs, such as hotel and travel workers, cashiers, and food service workers; and a wide range of jobs carried out in predictable settings, such as assembly line workers, dishwashers, food preparation workers, drivers, and agricultural and other equipment operators. Helping individuals transition from the declining occupations to growing ones will be a large-scale challenge.

The coming workforce transitions among occupations could be very large

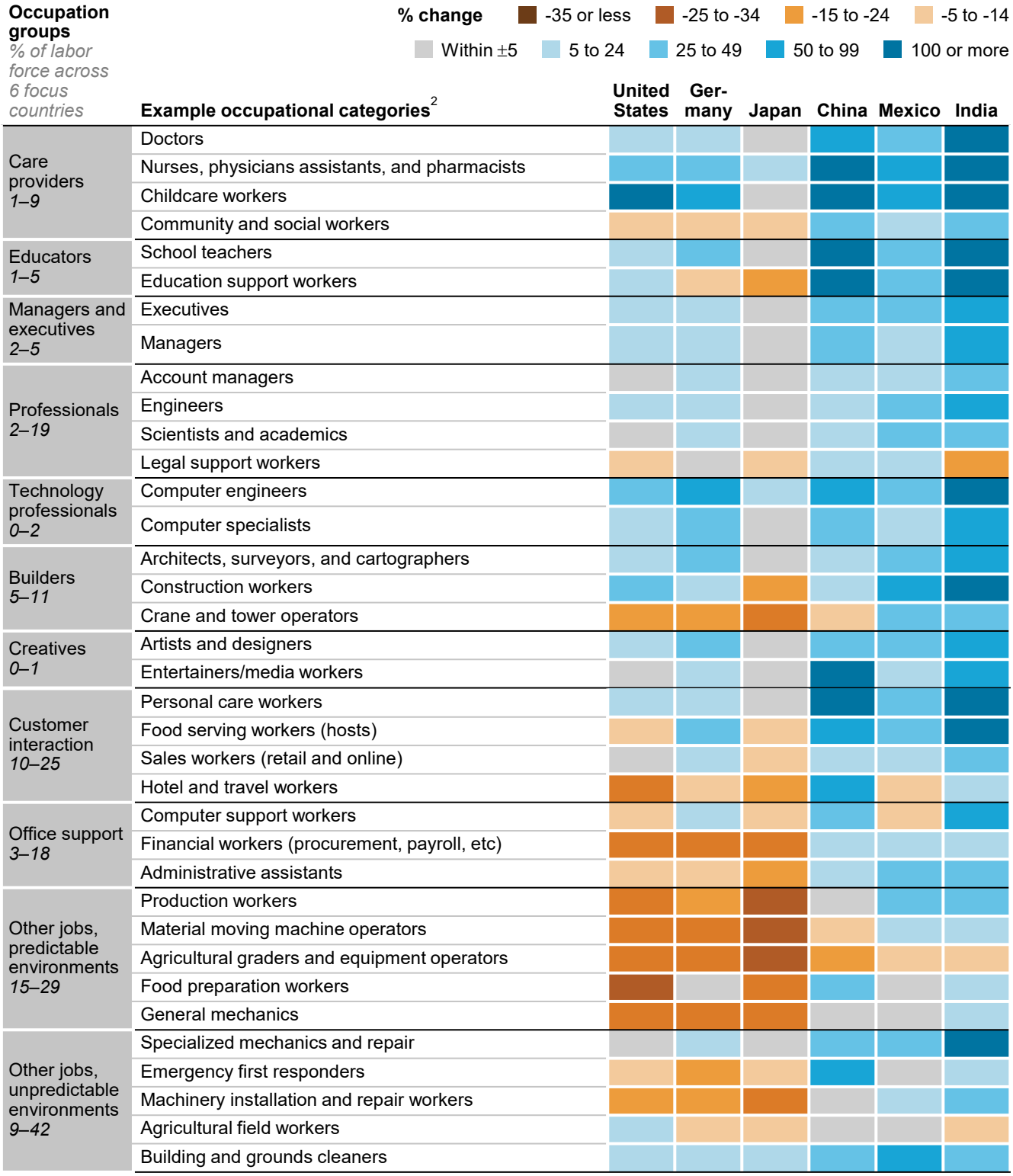
The changes in net occupational growth or decline imply that a very large number of people may need to shift occupational categories and learn new skills in the years ahead. The shift could be on a scale not seen since the transition of the labor force out of agriculture in the early 1900s in the United States and Europe, and more recently in China. But unlike those earlier transitions, in which young people left farms and moved to cities for industrial jobs, the challenge, especially in advanced economies, will be to retrain midcareer workers. There are few precedents in which societies have successfully retrained such large numbers of people. Frictions in the labor markets—including cultural norms regarding gender stereotypes in work and geographic mismatches between workers and jobs—could also impede the transition.[12]

[12] See Nicholas Eberstadt, *Men without work: America's invisible crisis*, Templeton Press, 2016.

Exhibit E5

Jobs of the future: Employment growth and decline by occupation

Net impact of automation and seven catalysts of labor demand, 2016–30
% change (+/–), step-up labor demand, midpoint automation[1]



1 Midpoint of earliest and latest automation adoption in the "step-up" scenario (i.e., high job growth). Some occupational data projected into 2016 baseline from latest available 2014 data.
2 A complete version of this heat map with all occupation groupings is in Chapter 3.

SOURCE: US Bureau of Labor Statistics; McKinsey Global Institute analysis

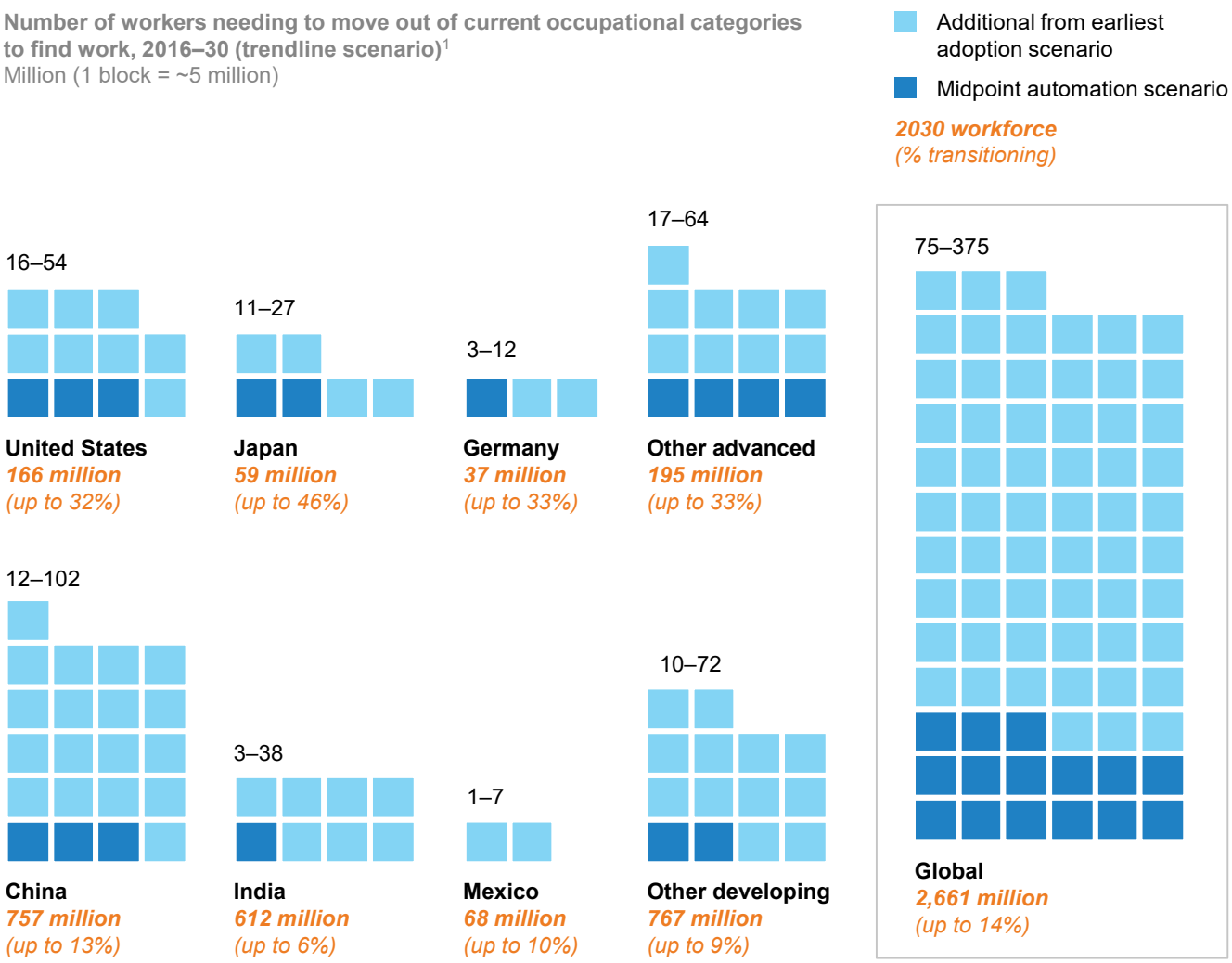
Up to
1/3
of workforce in the United States and Germany may need to find work in new occupations

We estimate that between 400 million and 800 million individuals could be displaced by automation and need to find new jobs by 2030 around the world, based on our midpoint and earliest (that is, the most rapid) automation adoption scenarios. We think demand for jobs will be there, based on our scenarios of future labor demand and the net impact of automation, as described in the next section. However people will need to find their way into these jobs. Of the total displaced, 75 million to 375 million may need to switch occupational categories and learn new skills, under our midpoint and earliest automation adoption scenarios (Exhibit E6).[13] Under the latest adoption scenario (that is, the slowest), this number would be far lower, below 10 million. Given the minimal impact on the workforce of this edge-case scenario, we have not highlighted it in the exhibits in this report. In absolute terms, China faces the largest number of workers needing to switch occupations—up to 100 million if automation is adopted rapidly, or 12 percent of the 2030 workforce—although this figure is relatively small compared with the huge shift in China out of agriculture in the past 25 years. For advanced economies, the share of the workforce that may need to learn new skills and find work in new occupations is much higher: up to one-third of the 2030 workforce in the United States and Germany, and nearly half in Japan.

Exhibit E6

Globally, up to 375 million workers may need to switch occupational categories

Number of workers needing to move out of current occupational categories to find work, 2016–30 (trendline scenario)[1]
Million (1 block = ~5 million)



1 Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: U.S. Bureau of Labor Statistics; McKinsey Global Institute analysis

[13] Analysis conducted by segmenting all US Bureau of Labor Statistics occupations into 58 occupational categories. See technical appendix.

WILL THERE BE ENOUGH WORK IN THE FUTURE?

Today there is growing concern about whether there will be enough jobs for workers given potential automation. History would suggest that such fears may be unfounded: over time, labor markets adjust to changes in demand for workers from technological disruptions, although at times with depressed real wages. We address this question about the future of work through two different sets of analyses: one based on modeling of a limited number of catalysts of new labor demand and automation described above, and one using a macroeconomic model of the economy that incorporates the dynamic interactions among variables. We also note that if history is any guide, we could expect 8 to 9 percent of 2030 labor demand will be in new types of occupations that have not existed before.[14] Both analyses lead us to conclude that, with sufficient economic growth, innovation, and investment, there can be enough new job creation to offset the impact of automation, although in some advanced economies additional investments will be needed as per our step-up scenario to reduce the risk of job shortages. But a larger challenge will be ensuring that workers have the skills and support needed to transition to new jobs. Countries that fail to manage this transition could see rising unemployment and depressed wages.

Future jobs lost and jobs gained vary by country, with the largest disruptions expected in advanced economies

The magnitude of future job creation from the trends described above and the impact of automation on the workforce vary significantly by country, depending on four factors:

- **Wage levels.** Higher wages make the business case for automation adoption stronger. However, low-wage countries may be affected as well, if companies adopt automation to boost quality, achieve tighter production control, move production closer to end consumers in high-wage countries, or other benefits beyond reducing labor costs. Some economists worry about "premature deindustrialization" in developing countries due to automation.[15]

- **Demand growth.** Economic growth is essential for job creation; economies that are stagnant or growing slowly create few if any net new jobs. Countries with stronger economic and productivity growth and innovation will therefore be expected to experience more new labor demand, although the amount and nature of job creation will vary depending on the sectors that drive growth.

- **Demographics.** Demographics affect both labor demand and labor supply. Countries with a rapidly-growing workforce, such as India, may enjoy a "demographic dividend" that boosts GDP growth—if young people are employed. Countries with a shrinking workforce, such as Japan, can expect lower future GDP growth, derived only from productivity growth. However, countries with a declining workforce need automation to offset their shrinking labor supply, while countries with growing workforces have greater job creation challenges.

- **Mix of economic sectors and occupations.** The automation potential for countries reflects the mix of economic sectors and the mix of jobs within each sector. Japan, for example, has a higher technical automation potential than the United States because the weight of sectors that are highly automatable, such as manufacturing, is higher. And within Japanese manufacturing, a larger proportion of jobs involve activities that can be more easily automated, such as production, than in the United States.

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[14] Ibid. Jeffrey Lin, "Technological adaptation," May 2011.

[15] For instance, see Dani Rodrik, "Premature deindustrialization," *Journal of Economic Growth*, volume 21, number 1, 2016.

These factors combine to create different outlooks for the future of work in each country (Exhibit E7). For instance, Japan is rich but its economy is projected to grow slowly to 2030. It faces the combination of slower job creation coming from economic expansion and a large share of work that can be automated as a result of high wages and the structure of its economy. However, Japan will also see its workforce shrink by 2030 by four million people. In the step-up scenario, and considering the jobs in new occupations we cannot envision today, Japan's net change in jobs could be roughly in balance.

Like Japan, the United States and Germany could also face significant workforce displacement from automation by 2030, but their projected future growth—and hence new job creation—is higher. The United States has a growing workforce and, in the step-up scenario, with innovations leading to new types of occupations and work, Germany's workforce will decline by three million by 2030, and it will have more than enough labor demand to employ all workers.

138M
Growth in India's labor force by 2030

At the other extreme is India: a fast-growing developing country with relatively modest potential for automation over the next 15 years, reflecting low wage rates. Our analysis finds that most occupational categories are projected to grow in India, reflecting its potential for strong economic expansion. However, India's labor force is expected to grow by 138 million people by 2030, or about 30 percent. Employing these new entrants in formal sector jobs will require job creation on a much larger scale than in the past. Automation will make this challenge more difficult; some fear "jobless growth."[16] However, our analysis suggests that India can create enough new jobs to offset automation and employ new entrants, if it undertakes the investments in our step-up scenario.

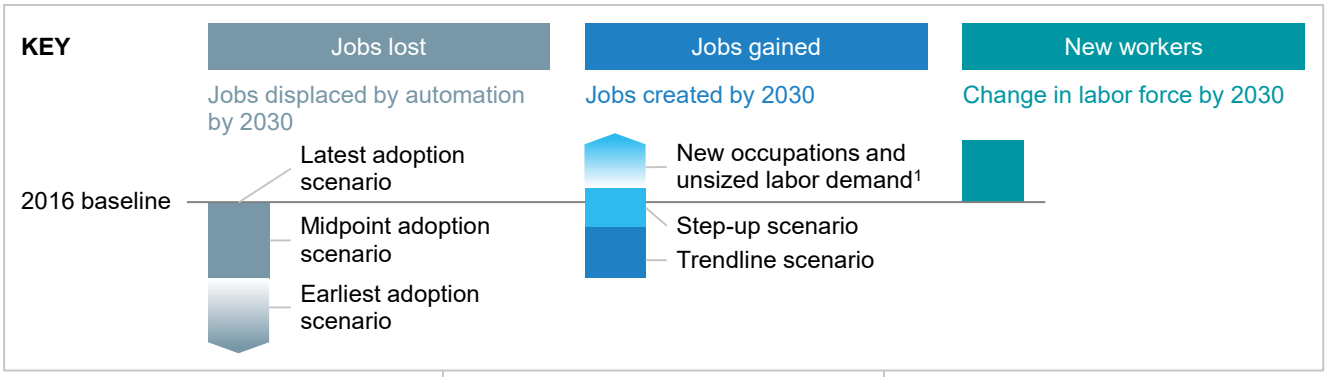
China and Mexico have higher wages than India, and so are likely to see more automation. China is still projected to have robust economic growth and will have a shrinking workforce; like Germany, China's problem could be a shortage of workers. Mexico's projected rate of future economic expansion is more modest, and its workforce will grow by 15 million by 2030. Like the United States and Japan, our results suggest that Mexico could benefit from the job creation in the step-up scenario plus innovation in new occupations and activities to make full use of its workforce.

[16] See *India's labor market: A new emphasis on gainful employment*, McKinsey Global Institute, June 2017.

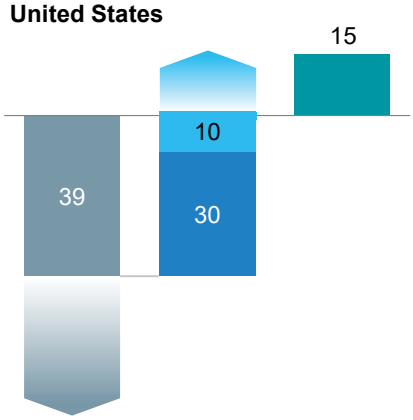
Exhibit E7

Jobs lost, jobs gained: Automation, new job creation, and change in labor supply, 2016–30

Range of automation scenarios and additional labor demand from seven catalysts

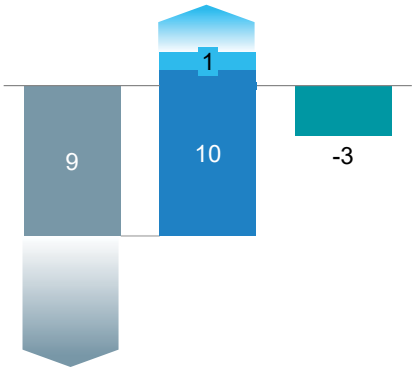


United States



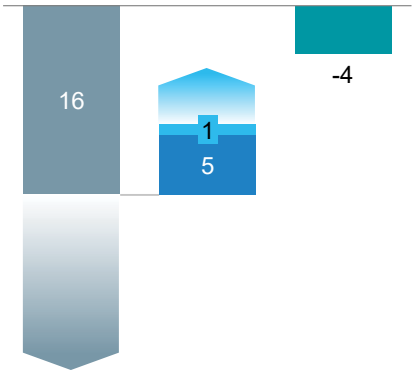
Enough jobs are created in the **step-up scenario** (along with growth in new occupations) to offset both automation and the growth in labor force

Germany



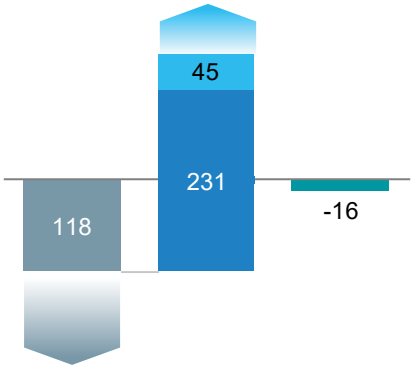
Enough jobs are created in the **trendline scenario** to offset effects of automation and the decline in the labor force

Japan



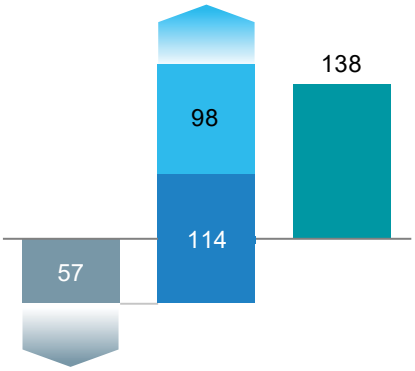
Enough jobs are created in the **step-up scenario** to offset automation and the decline in the labor force, if innovation creates sufficient new work activities

China



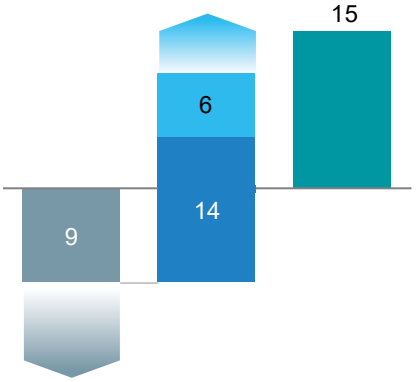
Enough jobs are created in the **trendline scenario** to offset effects of automation and the decline in labor force

India



Enough jobs are created in the **step-up scenario** to offset both automation and the growth in labor force

Mexico



Enough jobs are created in the **step-up scenario** to offset automation and the growth in labor force, given innovation in new work activities

1 Historical analysis suggests that we could expect 8–9% of 2030 labor supply will be in "new jobs," which is additional to labor demand we have estimated.
NOTE: We identified seven catalysts of labor demand globally: rising incomes, health-care spending, investment in technology, buildings, infrastructure, and energy, and the marketization of unpaid work. We compared the number of jobs to be replaced by automation with the number of jobs created by our seven catalysts as well as change in labor force, between 2016 and 2030. Some occupational data projected into 2016 baseline from latest available 2014 data. Not to scale.

SOURCE: McKinsey Global Institute analysis

If displaced workers are not reemployed quickly, countries will face rising unemployment and depressed wages

To model the impact of automation on overall employment and wages, we use a general equilibrium model of the economies of our six focus countries that takes into account the economic impacts of automation and dynamic interactions.[17] The model is not intended to forecast the future, but rather is a tool to explore the implications of different scenarios.

Automation has at least three distinct economic impacts. Most attention has been devoted to the potential displacement of labor. But automation also may raise labor productivity: firms only adopt automation when doing so enables them to produce more or higher-quality output with the same or fewer inputs (including material, energy, and labor inputs). The third impact is that automation adoption raises investment in the economy, lifting short-term GDP growth. We model all three effects.[18] We also create different scenarios for how quickly displaced workers find new employment, based on historical data.

The results reveal that across different rates of re-employment, our six countries could expect to be at or very near full employment by 2030. Consistent with the historical experience, labor markets adjust to technological shocks. However, the model also illustrates the importance of reemploying displaced workers quickly. If displaced workers are able to be reemployed within one year, our model shows automation lifting the overall economy: full employment is maintained in both the short and long-term, wages grow faster than in the baseline model, and productivity is higher. However, in scenarios in which some displaced workers take years to find new work, unemployment rises in the short- to medium-term. The labor market adjusts over time and unemployment falls—but with slower average wage growth. In these scenarios, average wages end up lower in 2030 than in the baseline model, which could dampen aggregate demand and long-term growth. The pace of reemployment will be influenced by the effectiveness of retraining, the capacity of companies to innovate and, in some sectors, the elasticity of demand.

WORKERS WILL REQUIRE DIFFERENT SKILLS, AND WAGE POLARIZATION IN ADVANCED COUNTRIES COULD CONTINUE

In all six of our focus countries, we find that in general, the current educational requirements of the occupations that may grow are higher than those for the jobs displaced by automation. In advanced economies, occupations that currently require only a secondary education or less see a net decline from automation, while those occupations requiring college degrees and higher grow. In India and other emerging economies, we find higher labor demand for all education levels, with the largest number of new jobs in occupations requiring a secondary education but the fastest rate of job growth will be for occupations currently requiring a college or advanced degree (Exhibit E8). For all countries, increasing investments in education and workforce training will be a priority.

Moreover, we find that workers of the future will spend more time on activities that machines are less capable of, such as managing people, applying expertise, and communicating with others. They will spend less time on predictable physical activities, and on collecting and processing data, where machines already exceed human performance. The skills and capabilities required will also shift, requiring more social and emotional skills, and more advanced cognitive capabilities, such as logical reasoning and creativity.

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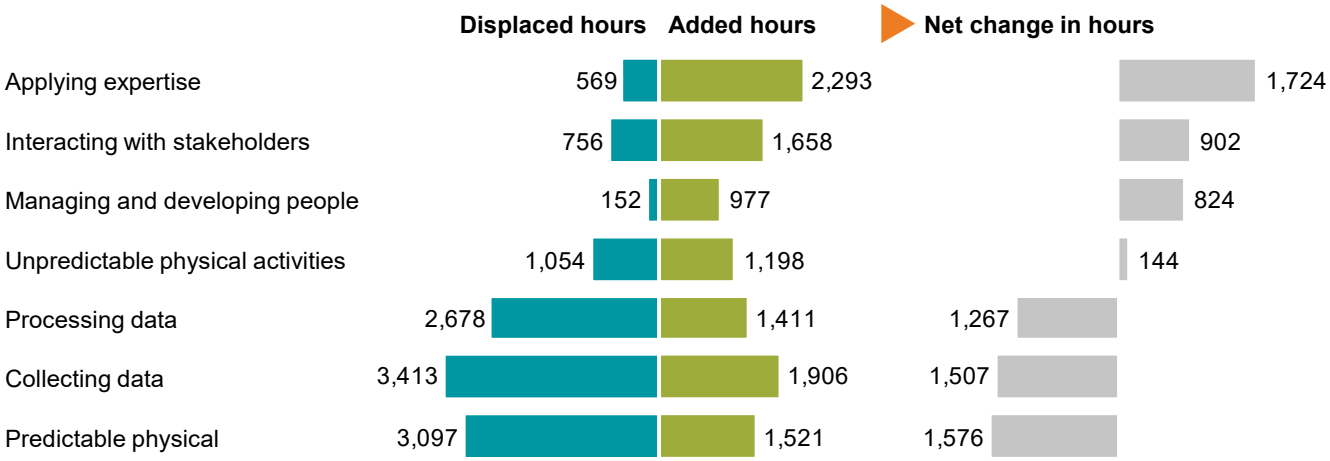
[17] We used McKinsey & Company's Global Growth Model, a supply-side general equilibrium macroeconomic model that covers more than 100 countries with data from 1960 through 2015.

[18] We obtain data for labor displacement and required firm investment from MGI's automation model, at the midpoint adoption scenario. We make a conservative assumption on the productivity impact of automation, that firms produce the same value of output as prior to automation but with fewer workers. See technical appendix for more detail.

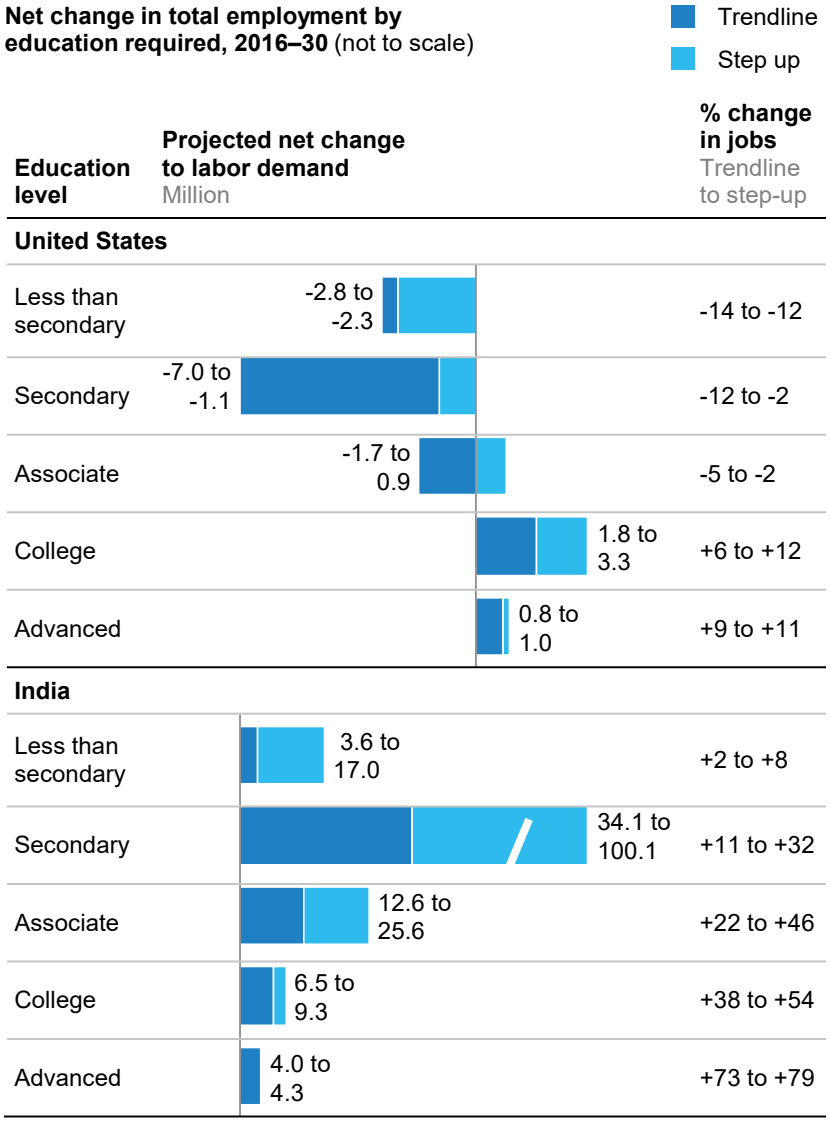
Exhibit E8

Potential shifts for activities, educational requirements, and wages

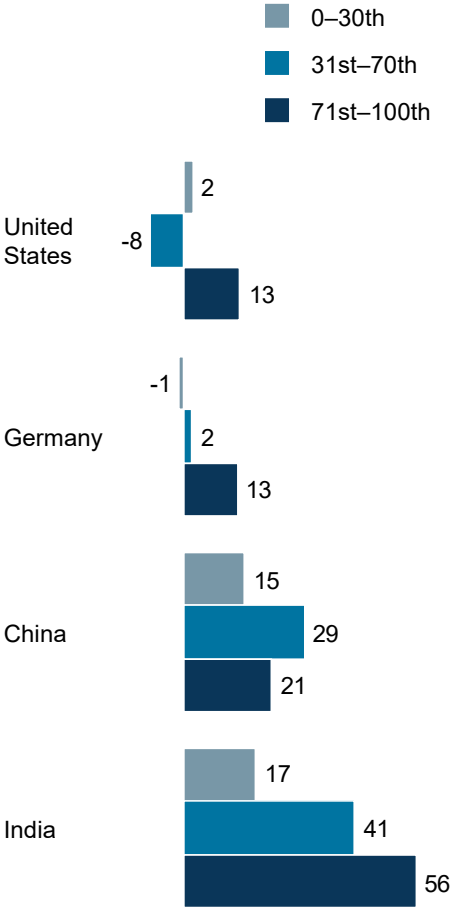
Net growth in work will involve more application of expertise, interaction, and management: Germany example
Total work hours by activity type, 2016–30 (Midpoint automation, step-up demand) (million)



Net change in total employment by education required, 2016–30 (not to scale)



Middle-wage jobs may fare well in emerging economies but lose out in advanced economies
Net job change by wage tercile, step-up scenario
% ± change from 2030 labor supply due to automation and labor demand catalysts



NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: ONET skill classification, US Bureau of Labor Statistics; McKinsey Global Institute analysis

Wage polarization could be exacerbated in advanced economies but developing countries will see a growing middle class

Wages may stagnate or fall in declining occupations. Although we do not model shifts in relative wages across occupations, the basic economics of labor supply and demand suggests that this should be the case for occupations in which labor demand declines. Since 1980, most advanced economies have seen an overall declining share of national income being captured by labor (compared with capital). Recent academic work suggests that technological change is one reason for this decline.[19]

Our analysis, looking at changes in employment by occupation at today's relative wage levels, shows that most job growth in the United States and other advanced economies will be in occupations currently at the high end of the wage distribution. Some occupations that are currently low-wage, such as nursing assistants and teaching assistants, will also increase, while a wide range of middle-income occupations will have the largest employment declines. These results suggest that income polarization could continue. Policy choices we identified in our step-up scenario, such as increasing investments in infrastructure, buildings, and energy transitions could help create additional demand for middle-wage jobs such as construction workers in advanced economies.

The wage trend picture is quite different in emerging economies such as China and India, where our scenarios show that middle-wage jobs such as retail salespeople and teachers will grow quickly as these economies develop. This implies that their consuming class will continue to grow in the decades ahead. However, our analysis comes with several important caveats (see Box E2, "What could overstate or understate the impact scenarios assessed in this research—and what we have not considered").

BUSINESSES AND POLICYMAKERS WILL NEED TO ACT TO KEEP PEOPLE WORKING AS AUTOMATION IS ADOPTED

The benefits of AI and automation to users and businesses, and the economic growth that could come via their productivity contributions, are compelling. They will not only contribute to dynamic economies that create jobs, but also help create the economic surpluses that will enable societies to address the workforce transitions that will likely happen regardless. Faced with the scale of worker transitions we have described, one reaction could be to try to slow the pace and scope of adoption in an attempt to preserve the status quo. While this may limit the workforce transitions, it would affect the contributions that these technologies make to business dynamism and economic growth, via the contribution to productivity growth, and which in turn leads to jobs growth and prosperity. We should embrace these technologies but also address the workforce transitions and challenges they bring. In many countries, this may require an initiative on the scale of the Marshall Plan involving sustained investment, new training models, programs to ease worker transitions, income support, and collaboration between the public and private sectors.

Achieving the benefits of deploying automation, such as productivity growth, while addressing its challenges, is not impossible. During the transition out of agriculture, for example, the United States made a major investment in expanding secondary education, and for the first time required all students to attend. Called the High School Movement, this raised the rate of high school enrolment of 14- to 17-year-olds from 18 percent in 1910

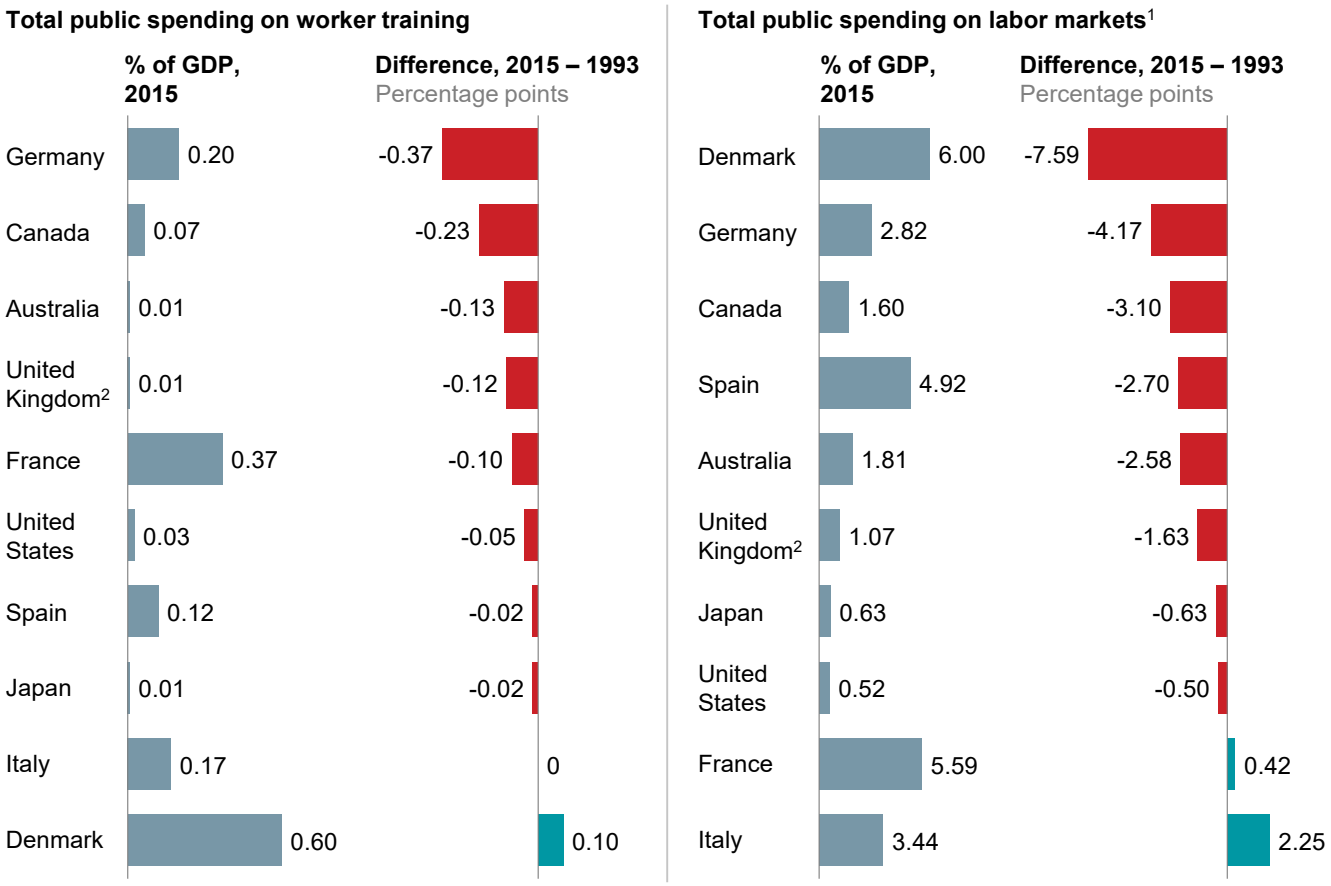
[19] See Lawrence H. Summers, "Economic possibilities for our children," The 2013 Martin Feldstein Lecture, *NBER Reporter Online*, number 4, 2013; Laura Tyson and Michael Spence, "Exploring the effects of technology on income and wealth inequality," in *After Piketty: The agenda for economics and inequality*, Heather Boushey, J. Bradford DeLong, and Marshall Steinbaum, eds, Harvard University Press, May 2017; Loukas Karabarbounis and Brent Neiman. "The global decline of the labor share," *The Quarterly Journal of Economics*, volume 129, number 1, February 2014.

to 73 percent in 1940, making the US workforce among the best-educated and most productive in the world, and enabling the growth of a vibrant manufacturing sector.[20]

Policy makers, business leaders, and individual workers all have constructive and important roles to play in smoothing workforce transitions ahead. History shows that societies across the globe, when faced with monumental challenges, often rise to the occasion for the well-being of their citizens. Yet over the last few decades, investments and policies to support the workforce have eroded. Public spending on labor force training and support has fallen in most OECD countries, and corporate spending on training has declined in the United States (Exhibit E9). Educational models have not fundamentally changed in 100 years; we still use systems designed for an industrial society to prepare students for a rapidly-changing knowledge economy. It is now critical to reverse these trends, with governments making workforce transitions and job creation a more urgent priority.

Exhibit E9

Most OECD countries have been spending less on worker training and labor markets over the past 20+ years



1 Public spending on employment incentives; startup incentives; direct job creation; out-of-work income maintenance and support; early retirement; public employment services and administration; and sheltered and supported employment and rehabilitation (excluding worker training).
2 2011 data used for United Kingdom.
NOTE: Countries where 1993 data was not available omitted. Not to scale.

SOURCE: OECD; *Labour market policy expenditure and the structure of unemployment*, Eurostat, 2013; McKinsey Global Institute analysis

[20] John Bound and Sarah Turner, "Going to war and going to college," *Journal of Labor Economics*, volume 20, number 4, October 2002.

Today, while policy choices will vary by country, all societies will need to address four key areas to smooth the looming workforce transitions:

- **Maintaining robust economic growth to support job creation.** Sustaining robust aggregate demand growth is critical to support new job creation, as is support for new business formation. Fiscal and monetary policies that ensure sufficient aggregate demand, as well as support for business investment and innovation, will be essential. Targeted initiatives in certain sectors could also help, including by increasing investment in infrastructure and energy transitions, as well as policies to enable a shift of unpaid household work such as childcare to the market, as discussed in our step-up scenario.

- **Scaling and reimagining job retraining and workforce skills development.** Providing job retraining and enabling individuals to learn marketable new skills throughout their lifetimes will be a critical challenge—and for some countries, the central challenge. Midcareer retraining will become ever more important as the skill mix needed for a successful career changes. A range of initiatives in countries from Sweden to Singapore may point the way to new approaches to improving skills or teaching new ones, including to older workers. Governments can play an important role here, as the US government did in previous eras with the GI Bill, which enabled just under eight million veterans returning from war to go to college or be retrained.[21] Programs that can more quickly retool the labor force by focusing on re-training and credentialing at the level of skills in demand rather than multi-year degrees could be important. Business can take a lead in some areas, including with on-the-job training and providing opportunities to workers to upgrade their skills, both through in-house training and partnerships with education providers.

- **Improving business and labor market dynamism including mobility.** Greater fluidity will be needed in the labor market to manage the difficult transitions we anticipate. This includes restoring now-waning geographic mobility in advanced economies including the United States. Digital talent platforms and the rise of the "gig" economy can foster fluidity, by matching workers and companies seeking their skills, and by providing a plethora of new work opportunities for those open to taking them.[22] Policy makers in countries with relatively inflexible labor markets can learn from others that have deregulated, such as Germany, which transformed its federal unemployment agency into a powerful job-matching entity. Governments may also update labor market regulations to ensure that gig economy jobs are not subject to discrimination, and that remaining uncertainties about worker benefits are resolved.

- **Providing income and transition support to workers.** Income support and other forms of transition assistance to help displaced workers find gainful employment will be essential. Beyond retraining, a range of policies can help, including unemployment insurance, public assistance in finding work, and portable benefits that follow workers between jobs. We know from history and from our analysis that wages for many occupations can be depressed for some time during workforce transitions. More permanent policies to supplement work incomes might be needed to support aggregate demand and ensure societal fairness. Possible solutions to supplement incomes, such as more comprehensive minimum wage policies, universal basic income, or wage gains tied to productivity, are all being explored.

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[21] Claudia Goldin, "America's graduation from high school: The evolution and spread of secondary schooling in the twentieth century," *Journal of Economic History*, volume 58, number 2, June 1998.

[22] See *A labor market that works: Connecting talent with opportunity in the digital age*, McKinsey Global Institute, June 2015.

Business leaders have much to gain by early adoption of automation technologies, enabling performance benefits such as quality and speed, as well as greater efficiency and productive use of all factors of production. Businesses will be on the front lines of the workplace as it changes. That will require them to both retool their business processes and re-evaluate their talent strategies and workforce needs, carefully considering which individuals are needed, which can be redeployed to other jobs, and where new talent may be needed. Many companies are finding it is in their self-interest—as well as important for societal responsibility—to train and prepare workers for a new world of work.

Individuals, too, will need to be prepared for a rapidly evolving future of work. Acquiring new skills that are in demand and resetting intuition about the world of work will be critical for their own well-being. There will be demand for human labor, but workers everywhere will need to rethink traditional notions of where they work, how they work, and what talents and capabilities they bring to that work. Ultimately, we will all need creative visions for how our lives are organized and valued in the future, in a world where the role and meaning of work start to shift.

•••

Automation represents both hope and challenge. The global economy needs the boost to productivity and growth that it will bring, especially at a time when aging populations are acting as a drag on GDP growth. Machines can take on work that is routine, dangerous, or dirty, and may allow us all to use our intrinsically human talents more fully. But to capture these benefits, societies will need to prepare for complex workforce transitions ahead. For policy makers, business leaders, and individual workers the world over, the task at hand is to prepare for a more automated future by emphasizing new skills, scaling up training, especially for midcareer workers, and ensuring robust economic growth.

Box E2. What could overstate or understate the impact scenarios assessed in this research—and what we have not considered

We analyze scenarios for the net impact of automation and future labor demand on employment, skills, and wages. Most of them suggest that, while there will be enough work to maintain full employment in the long term, ensuring that displaced workers have the skills and support needed to obtain the new jobs will be critical. If workers are not re-employed quickly, the impact on wage growth could be negative. This conclusion could overstate or understate the impact.

On the one hand, the future disruption could be smaller than we anticipate for several reasons:

- Adopting automation requires significant investments and redesign of business processes, and companies have been slow to adopt digital technologies, let alone recent forms of AI and automation.[1] In our slowest automation adoption scenario, less than 5 percent of work is automated by 2030, so the overall impact on the economy could be minimal.
- In our analysis, we make the strong assumption that every hour of work that is automated results in one hour less of work for a full-time equivalent employee. But companies often choose to redefine occupations, or redeploy some workers instead. For instance, after the introduction of the ATM, the number of bank tellers in the United States continued to grow for many years, even as the activities they performed changed.[2]
- Our model of the seven catalysts of labor demand does not take into account dynamic effects within the economy, and they represent only a partial list of future sources of labor demand. If automation adoption is rapid, future productivity growth could be higher than we model, and this could raise incomes and result in more job creation than we anticipate. This could offset the labor displacement, even during the transition.

On the other hand, the impact of automation on work could be more disruptive than we anticipate for several reasons:

- The development of automation technologies, including AI, could accelerate or break through new frontiers. AI researchers today say that machine learning has unlocked more rapid improvements in the technology than could have been imagined even a few years ago. Improvements in machine capabilities in areas such as natural language understanding and generation could mean that more work might be automated more rapidly than we estimate here.
- While we assume that wage levels will play a major role in determining automation adoption, companies may also adopt these technologies for other reasons, including their capacity to exceed human performance capabilities in some areas. This would mean more rapid automation adoption than we model, particularly in low-wage economies and for low-wage work in advanced economies.
- Displaced workers might not find new work quickly, or at all, because they lack the skills or educational requirements, or because other barriers such as cultural preferences or geographic mobility stand in their way. There are few examples of large-scale retraining and redeployment of midcareer workers. Moreover, labor markets may not work as well as they need to do to help displaced workers find new employment.
- The assumptions we make on future consumption growth and spending on infrastructure and buildings might be too optimistic. In the past decade, actual GDP growth in nearly all advanced economies has been lower than forecast. Continued sluggish growth, rising geopolitical tensions, or a new recession could make our future job creation scenarios too optimistic.

A number of other caveats to our findings should also be noted. We have not made assumptions in our modeling about sector trends, such as the growth of ecommerce in retailing, or the impact of fiscal constraints on public sector employment. We also do not model changes in work structure, such as the growth of the gig economy, or activities within an occupation that could change as a result of technological innovation. Our analysis of wage trends is based on current average wages for each occupation in each country, and we do not model wages over time by occupation based on the dynamics of labor supply and demand. Finally, we do not model changing skill requirements for occupations or analyze the "skill bias" of automation technologies, that is, whether they will enable high-skill workers at the expense of low-skill ones, or vice-versa.[3]

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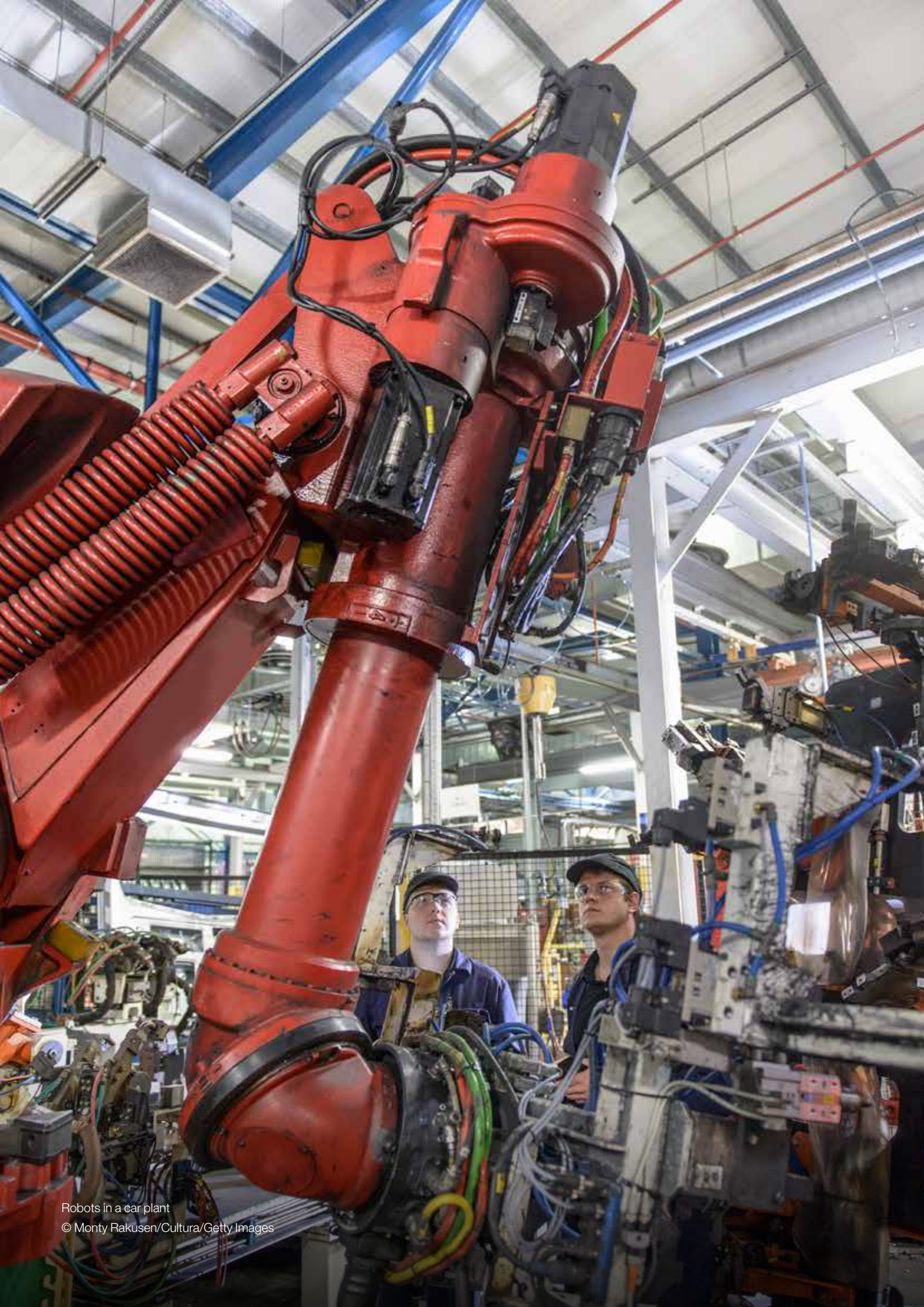
1 See *Artificial intelligence: The next digital frontier?* McKinsey Global Institute, June 2017; *Digital America: A tale of the haves and have-mores*, McKinsey Global institute, December 2015, and *Digital Europe: Pushing the frontier, capturing the benefits*, McKinsey Global Institute, June 2016.

2 James Bessen, *Learning by doing: The real connection between innovation, wages, and wealth*, Yale University Press, 2015.

3 For a discussion of skill bias, see David H. Autor, Frank Levy, and Richard J. Murnane, "The skill content of recent technological change: An empirical exploration," *The Quarterly Journal of Economics*, volume 18, number 4, November 2003.



Robots in a car plant
© Monty Rakusen/Cultura/Getty Images

1. JOBS LOST, JOBS CHANGED: IMPACT OF AUTOMATION ON WORK

We live in an age when machines answer customer inquiries, help doctors understand X-rays, lip-read better than human professionals, and sort trash into compost and recyclables—an age, too, when the public debate about automation and its impact on the workplace raises anxious questions. First is the existential one about the future of work itself. Given rapid advances in technologies including robotics and artificial intelligence, will there be enough work to ensure full employment? Second is the question about what those jobs will be, and which skills will be needed for them. The third is what all this could mean for wages.

We seek to address these questions in this report through, first, an analysis of automation potential and scenarios about the extent of adoption of current work activities by 2030 and, second, an analysis of potential future labor demand. We looked at 46 countries, representing almost 90 percent of global GDP. To illustrate the potential impact at a country level, we use six as exemplars of countries that vary by sector and occupation mix, GDP per capita growth, wage rates, and demographics: China, Germany, India, Japan, Mexico, and the United States.[23]

In this chapter, we focus on automation's potential to transform the workplace. Building on our previous automation work, we create a range for the number of hours that could be displaced by automation by 2030, and seek to identify the work activities, occupations, and sectors that are most—and least—susceptible to being automated (see Box 1, "Automation's rapid advances and its limitations—for now").[24]

Among the findings of our new research are that as much as 30 percent of the hours worked globally could be automated by 2030, depending on the speed of adoption, with 15 percent of current work activities being automated in our midpoint scenario. The speed of adoption depends on factors including technical feasibility, the pace of technology development, costs, and social and regulatory acceptance. These results differ significantly by country, reflecting the mix of activities currently performed by workers and prevailing wage rates, ranging from 9 percent in India to 26 percent in Japan in the midpoint adoption rate scenario.

[23] See the technical appendix for details of our modeling.

[24] See *A future that works: Automation, employment, and productivity*, McKinsey Global Institute, January 2017.

Box 1. Automation's rapid advances and its limitations—for now

Automation is not a new phenomenon; industrial robots have been a fixture on factory floors for several decades, and software algorithms help logistics companies optimize the route planning of deliveries in a faster and more efficient manner than human route planners could.

Recent developments in robotics, artificial intelligence, and machine learning are noteworthy for the advances they represent, however. We are on the cusp of a new automation age in which technologies not only do things we thought only humans could do, but can increasingly do them at a superhuman level. In just the past year, a project by Google's DeepMind and the University of Oxford has applied deep learning to a huge data set of BBC programs to create a lip-reading system that is substantially more proficient than a professional human lip-reader.[1] Researchers at Stanford University have developed a deep learning system that is able to diagnose pneumonia from chest x-rays better than expert radiologists working alone.[2] Robot "skin" made of a piezotronic transistor mesh developed by the Georgia Institute of Technology and covered in thousands of mechanical hairs can "feel" textures and find objects by touch.[3] Companies are using advanced facial analysis to monitor emotional responses to advertisements and other digital media content, via a webcam.[4]

AI is already being deployed in synthetic biology, cancer research, climate science, and material science. For example, researchers at Vanderbilt university have used computers to exceed the human standard in predicting the most effective treatment for major depressive disorders and eventual outcomes of breast cancer patients.[5]

Three factors are driving the technological advances:

- Machine-learning algorithms have progressed in recent years, especially through the development of deep learning and reinforcement-learning techniques based on neural networks.
- Computing capacity is increasing exponentially and has become available to train larger and more complex models much faster. Graphics processing units, originally designed to render the computer graphics in video games, have been repurposed to execute the data and algorithm crunching required for machine learning at speeds many times faster than traditional processor chips. This computing capacity has been aggregated in hyper-scalable data centers and made accessible to users through the cloud.
- Vast amounts of data that can be used to train machine learning models are being generated, for example through daily creation of billions of images, online click streams, voice and video, mobile locations, and sensors embedded in the Internet of Things.

Formidable technical challenges still lie ahead. While machines can be trained to perform a range of cognitive tasks, they remain limited. They are not yet good at putting knowledge into context, let alone improvising, and they have little of the common sense that is the essence of human experience and emotion. They struggle to operate without a pre-defined methodology. They can replicate fugues in the style of Bach, but cannot yet understand sarcasm or love.[6]

One of the biggest remaining technical challenges is mastery of natural language processing—understanding and generating speech. These capabilities are indispensable for numerous work activities but, despite great progress in areas such as machine translation, machines still have far to go to achieve human levels of performance.

Beyond the development of technology, much work remains to be done integrating different capabilities into holistic solutions in which everything works together seamlessly. Combining a range of technologies will be essential for workplace automation, but engineering such solutions—whether for hardware or software—is a difficult process.

1 Hal Hodson, "Google's DeepMind AI can lip-read TV shows better than a pro," *New Scientist*, November 21, 2016.
2 Taylor Kubota,"Stanford algorithm can diagnose pneumonia better than radiologists," *Stanford News*, November 15, 2017.
3 Klint Finley, "Syntouch is giving robots the ability to feel textures like humans do," *Wired*, December 17, 2015.
4 Molly Reynolds, "How facial recognition is shaping the future of marketing innovation," *Inc.*, February 16, 2017.
5 Xia Li et al., "An algorithm for longitudinal registration of PET/CT images acquired during neoadjuvant chemotherapy in breast cancer: preliminary results," *EJNMMI Research*, December 2012.
6 Dave Gershgorn, "You probably can't tell the difference between Bach and music written by AI in his style," *Quartz*, December 15, 2016. A sample of harmonization in the style of Bach generated using deep learning, posted by Sony CSL, can be listened to on YouTube at https://www.youtube.com/watch?v=QiBM7-5hA6o.

About
50%
of the time spent on work activities in the global economy could theoretically be automated by adapting currently demonstrated technologies

AUTOMATION CAN RAISE THE PRODUCTIVITY OF THE GLOBAL ECONOMY BUT WILL AFFECT EMPLOYMENT: A BRIEF RECAP OF OUR PRIOR RESEARCH

In our January 2017 report, *A future that works: Automation, employment, and productivity*, we noted that automation technologies such as advanced robotics and artificial intelligence are powerful drivers of productivity and economic growth which can help create economic surpluses and increase overall societal prosperity. Key findings of that report include:

- Automation could accelerate the productivity of the global economy by between 0.8 and 1.4 percent of global GDP annually, assuming that human labor replaced by automation rejoins the workforce and is as productive as it was in 2014. Automation on its own will not be sufficient to achieve long-term economic growth aspirations across the world; for that, additional productivity-boosting measures will be needed, including reworking business processes or developing new products and services. Nonetheless, the productivity growth enabled by automation can ensure continued prosperity in aging nations and provide an additional boost to fast-growing ones.[25]

- For companies, the deployment of automation can deliver benefits in the form of labor cost savings, but also in myriad other performance-enhancing ways. It can enable firms to get closer to customers and predict maintenance needs, sharply reducing the cost of operations in some activities and extending the life of existing capital assets. Automation can also increase scale and speed. Nissan, for example, has halved the time it takes to move from final product design to production thanks to an automated system, while BMW has reduced machine downtime by 30 to 40 percent—effectively generating fresh economies of scale with minimal investment—through AI-enabled condition-based maintenance.[26] Exhibit 1 compares the estimated potential performance and labor cost reduction benefits from automation for a number of key processes within some sectors. These findings are based on estimates of potential in case studies informed by our work with industry.

- Overall, our analysis suggested that roughly 50 percent of the time spent on activities that people are paid almost $15 trillion to do in the global economy have the theoretical potential to be automated by adapting currently demonstrated technology—in other words, the technical capabilities already exist, although an integrated solution to automate each particular activity might not yet have been developed nor deployed. We estimated the potential for technology to automate the more than 2,000 work activities in about 800 occupations across the economy, by adapting currently demonstrated technologies. (We examined work activities individually rather than whole occupations, since occupations consist of a range of activities with different potential for automation). Certain categories of activity are more susceptible to automation than others.[27] While less than 5 percent of occupations can be fully automated, about 60 percent have at least 30 percent of activities that can technically be automated (see illustration, "Automation: A global force that will transform economies and the workforce").

- Our automation analysis found significant variation among sectors of the economy, and among the occupations within those sectors. For example, almost one-fifth of the time spent in US workplaces involves predictable physical activity and is prevalent in such sectors as manufacturing and retail trade. Accordingly, these sectors have a relatively high technical potential for automation by adapting currently demonstrated technologies. Even within sectors, there is considerable variation. In manufacturing, for

[25] Even at historical rates of productivity growth, economic growth could be nearly halved as a result of this aging trend. *Global growth: Can productivity save the day in an aging world?* McKinsey Global Institute, January 2015.

[26] For details and further examples, see Michael Chui, Katy George, and Mehdi Miremadi, "A CEO action plan for workplace automation," *McKinsey Quarterly*, July 2017.

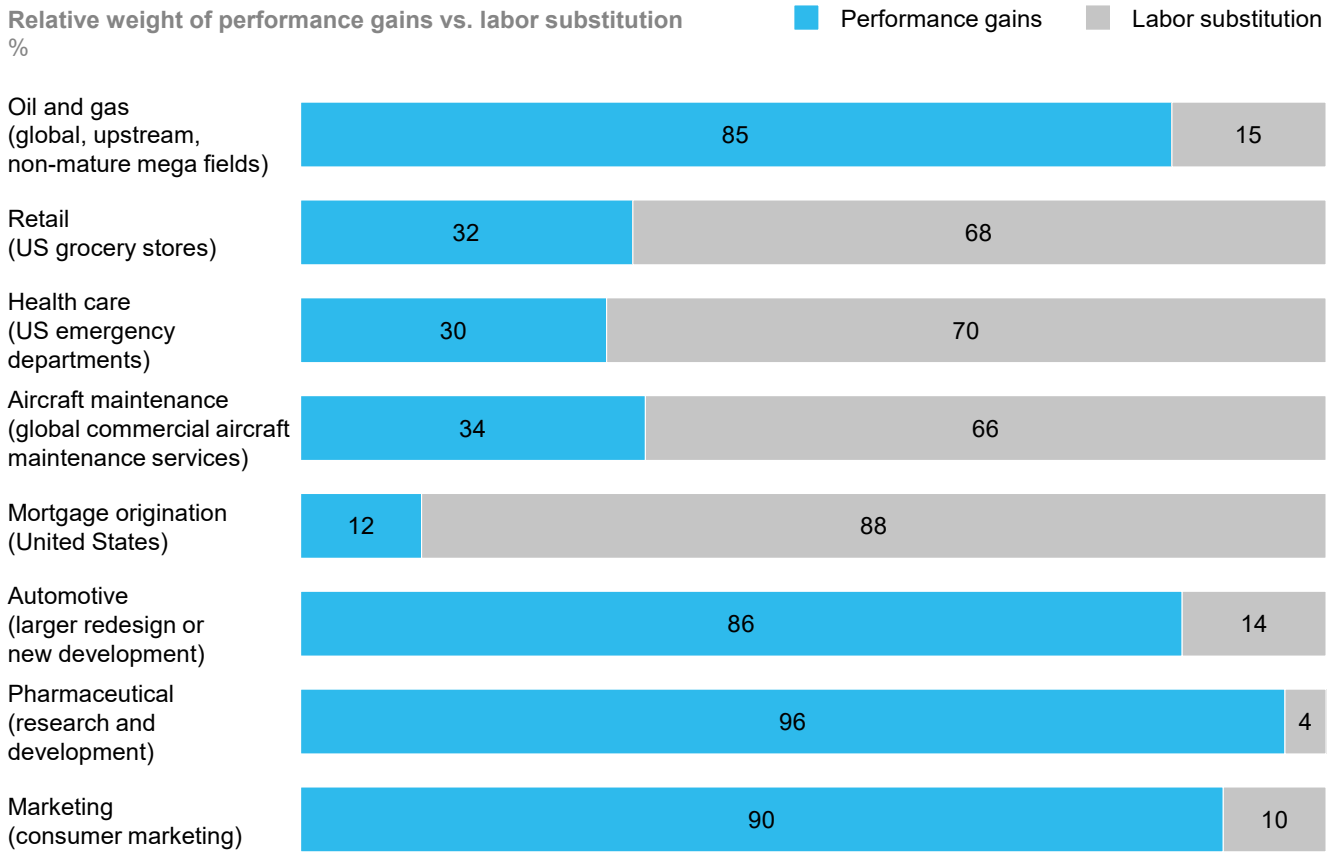
[27] Ibid.

example, occupations that have a large proportion of physical activities in predictable environments such as factory welders have a technical automation potential above 90 percent, whereas for customer service representatives that potential is less than 30 percent.

- Technical feasibility is an essential element of automation but four other factors also influence the timing, which explains in part why our overall analysis of automation adoption and the impact on employment to 2030 can vary among countries. The other factors are economic and social: the cost of developing and deploying automation solutions for the workplace—that is actually developing integrated solutions for specific use cases; labor market dynamics including the supply, demand, and cost of human labor; the net economic benefits of automation, which include performance benefits beyond labor substitution such as higher throughput, raised productivity, and heightened safety; and regulatory and social acceptance. Labor market dynamics in particular plays an important role in the national variations around automation adoption, since wage rates vary widely by country, even for similar occupations. The relative cost of automation compared with the cost of labor will affect adoption: if qualified workers are in abundant supply and significantly less expensive than automation, this could be a decisive argument against automation in that situation. Consequently, in the period to 2030, we expect advanced economies, with wage levels that are relatively higher, to adopt automation earlier than many emerging economies, especially if adoption requires expensive hardware solutions. That said, our automation modeling does consider the continuing improvement in automation technologies' capabilities over time, as well as decreasing costs.

Exhibit 1

Automation improves corporate performance in ways beyond simple labor substitution



SOURCE: McKinsey Global Institute analysis

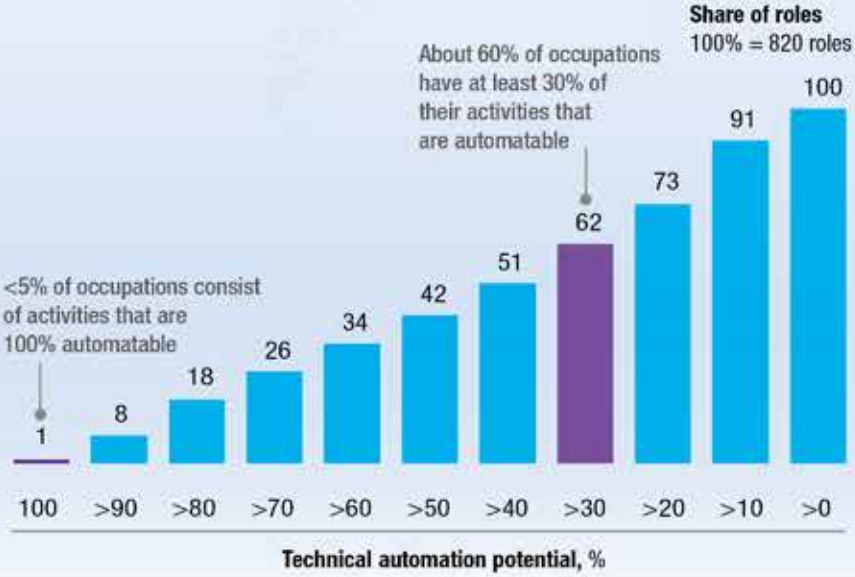
From the January 2017 MGI report, *A future that works: Automation, employment, and productivity*

AUTOMATION

A global force that will transform economies and the workforce

Technical automation potential by adapting currently demonstrated technologies

While few occupations are fully automatable, 60 percent of all occupations have at least 30 percent technically automatable activities



Wages associated with technically automatable activities
$ trillion

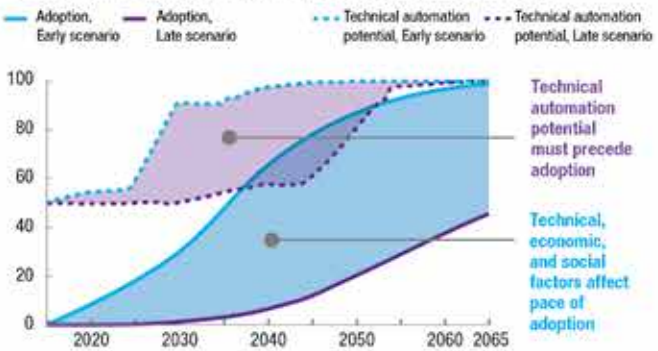
Labor associated with technically automatable activities
Million full-time equivalents (FTEs)

[1] France, Germany, Italy, Spain, and the United Kingdom.

Five factors affecting pace and extent of adoption

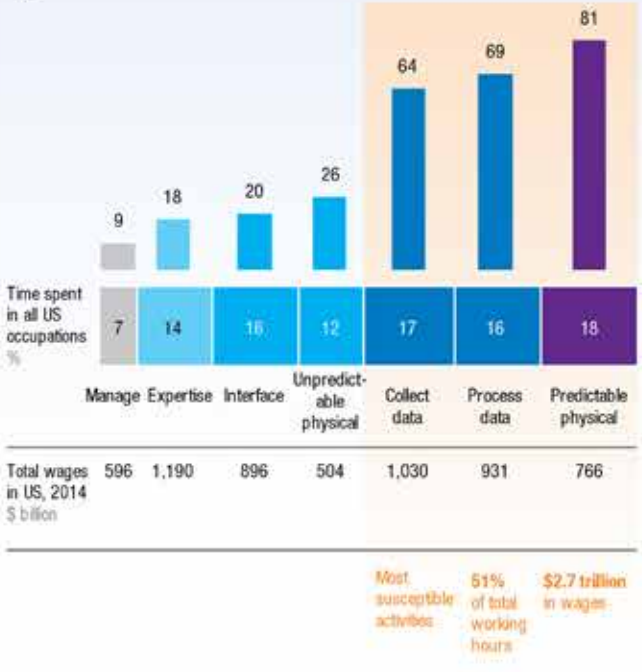
1. **TECHNICAL FEASIBILITY** Technology has to be invented, integrated, and adapted into solutions for specific case use
2. **COST OF DEVELOPING AND DEPLOYING SOLUTIONS** Hardware and software costs
3. **LABOR MARKET DYNAMICS** The supply, demand, and costs of human labor affect which activities will be automated
4. **ECONOMIC BENEFITS** Include higher throughput and increased quality, alongside labor cost savings
5. **REGULATORY AND SOCIAL ACCEPTANCE** Even when automation makes business sense, adoption can take time

Scenarios around time spent on current work activities, %



Three categories of work activities have significantly higher technical automation potential

Time spent on activities that can be automated by adapting currently demonstrated technology
%



MCKINSEY GLOBAL INSTITUTE

McKinsey&Company

15%
of work could be displaced by automation by 2030 in our midpoint adoption scenario

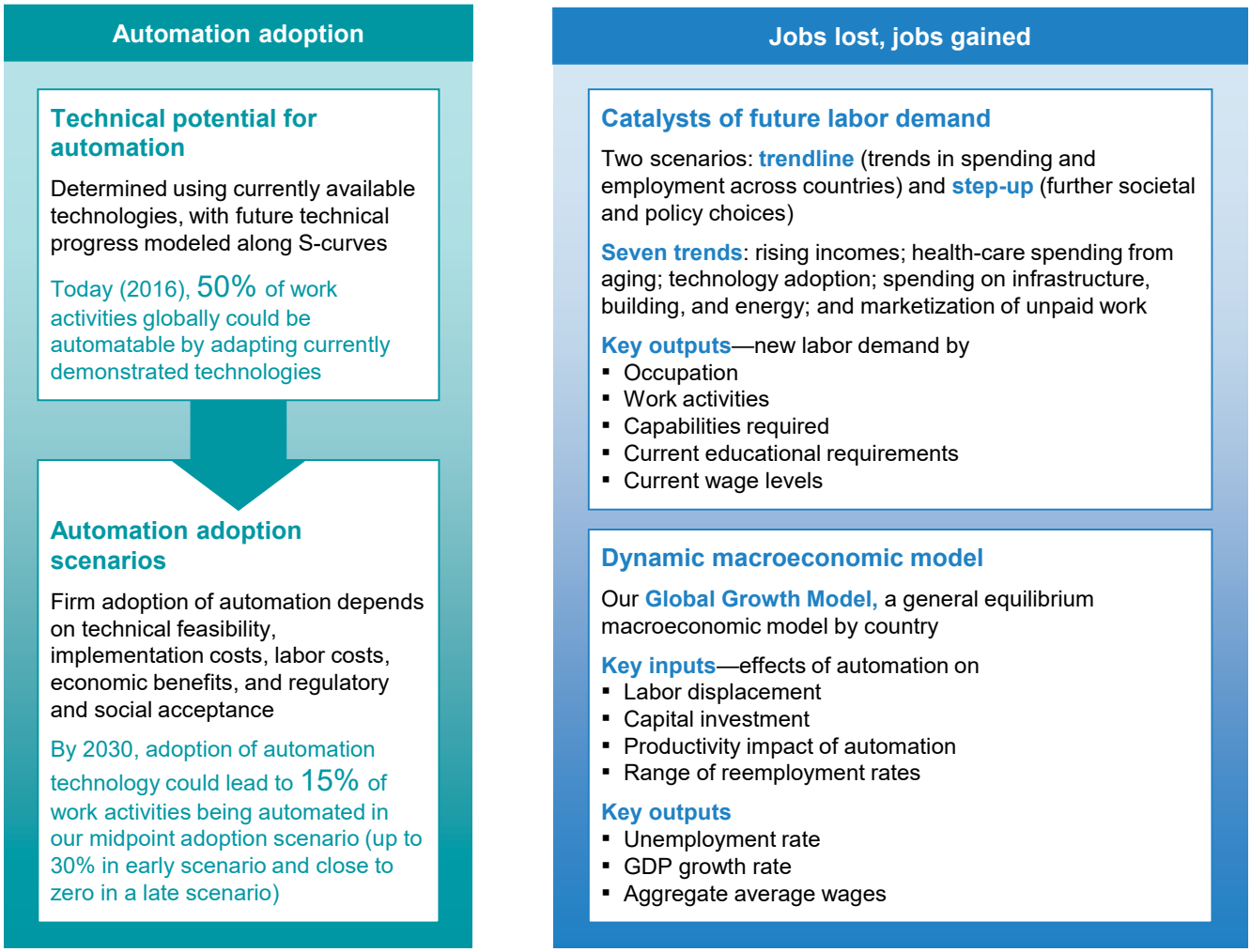
AUTOMATION COULD REPLACE 9 TO 26 PERCENT OF THE WORK HOURS IN OUR SIX FOCUS COUNTRIES BY 2030

Our automation model applies the factors listed above to a range of scenarios, bookended by two scenarios around the earliest adoption and latest adoption we modeled. It is not our intention to predict the timing but to provide a range, and these two edge case scenarios may turn out to be extreme. However, they do enable us to model a spectrum of outcomes.

While about half of all work activities globally have the technical potential to be automated by adapting currently demonstrated technologies, according to our prior research on automation, this will not happen overnight. Taking into account the technical, economic and social factors affecting the pace and extent of automation, described above, the proportion of work actually displaced by 2030 will likely be lower. We estimate that up to 30 percent of current work activities could be displaced by 2030, with a midpoint of 15 percent, or the hours of about 400 million full-time equivalents. Indeed, the range of outcomes is particularly wide in 2030 in our model; in the event of late automation adoption, the percentage of work activities displaced by 2030 would be close to zero. Among countries, too, especially between advanced economies and emerging ones, the range is wide. Exhibit 2 highlights both how we arrived at our range of automation scenarios, and the modeling we used for estimating scenarios for future labor demand, which we describe in detail in the following chapter.

Exhibit 2

Automation adoption and new labor demand: Arriving at our scenarios


Automation adoption
Technical potential for automation
Determined using currently available technologies, with future technical progress modeled along S-curves
Today (2016), 50% of work activities globally could be automatable by adapting currently demonstrated technologies
Automation adoption scenarios
Firm adoption of automation depends on technical feasibility, implementation costs, labor costs, economic benefits, and regulatory and social acceptance
By 2030, adoption of automation technology could lead to 15% of work activities being automated in our midpoint adoption scenario (up to 30% in early scenario and close to zero in a late scenario)
Jobs lost, jobs gained
Catalysts of future labor demand
Two scenarios: trendline (trends in spending and employment across countries) and step-up (further societal and policy choices)
Seven trends: rising incomes; health-care spending from aging; technology adoption; spending on infrastructure, building, and energy; and marketization of unpaid work
Key outputs—new labor demand by
Occupation
Work activities
Capabilities required
Current educational requirements
Current wage levels
Dynamic macroeconomic model
Our Global Growth Model, a general equilibrium macroeconomic model by country
Key inputs—effects of automation on
Labor displacement
Capital investment
Productivity impact of automation
Range of reemployment rates
Key outputs
Unemployment rate
GDP growth rate
Aggregate average wages

SOURCE: McKinsey Global Institute analysis

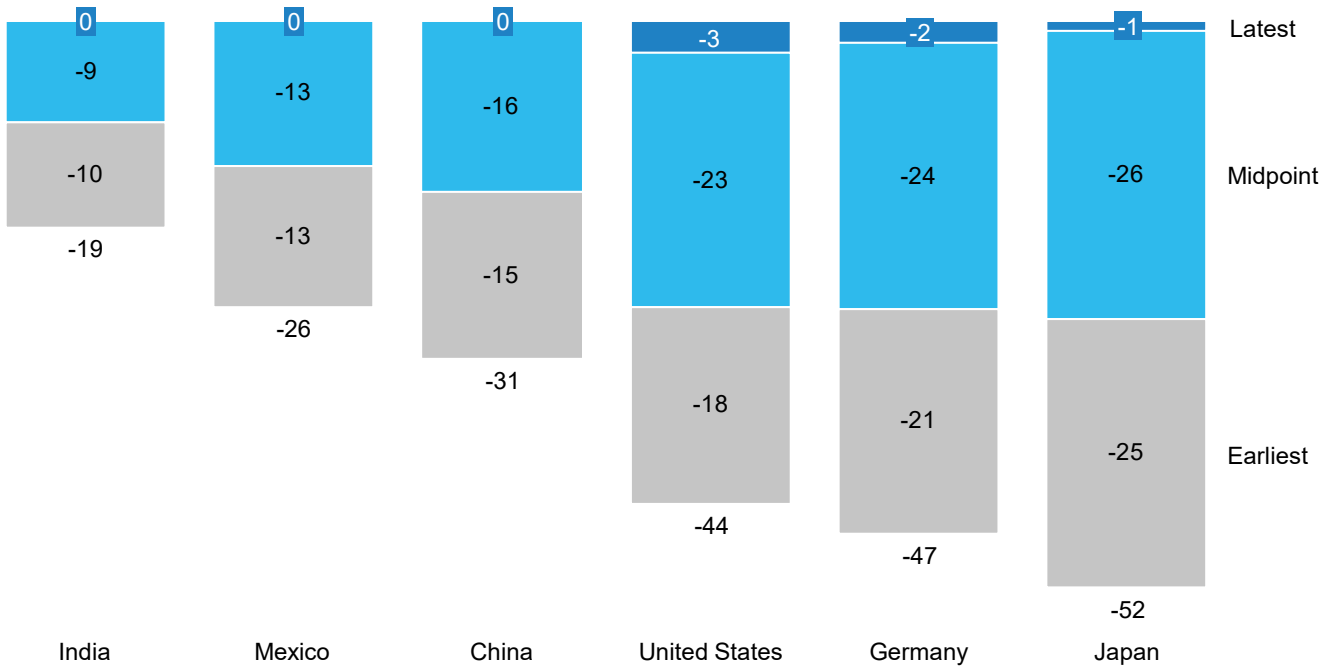
For the six countries we use as exemplars in this report, the hours that could be automated by 2030 in the midpoint adoption case range from 26 percent of the hours worked in Japan to 9 percent in India (Exhibit 3). Developed countries Germany (24 percent) and the United States (23 percent) are not far behind Japan, followed by China (16 percent) and Mexico (13 percent). In general, wage rates are the biggest determinant of the difference in automation scenarios among countries; higher wage rates make automation more economically attractive. In addition, the mix of activities, which is related to the mix of sectors and occupations, also affects the modeled rate of automation. Among the main differences between emerging and advanced economies is the importance of agriculture in the former. In Germany and Japan, manufacturing also has high automation potential. That said, emerging economies could leverage automation technologies aggressively in an effort to leapfrog their economic development. China, for example, has fewer robots per worker than the global average, but received nearly one-third of all robot shipments in 2016.[28]

At the other extreme of the scenarios we modeled, in our latest adoption scenario, less than 0.5 percent of work hours globally will be automated by 2030, and advanced economies will account for the large majority of them.

Exhibit 3

By 2030, in the midpoint adoption scenario, automation could replace up to 9–26% of current work in our focus countries, as high as 19–52% in the earliest adoption scenario and as low as 0–3% in the latest adoption scenario

Projected impact on total employment in midpoint automation scenario, 2016–30
% of FTE hours with potential to be automated, midpoint scenario (range of automation scenarios, latest to earliest)



NOTE: Numbers may not sum due to rounding.

SOURCE: McKinsey Global Institute analysis

[28] Grace Donnelly, "Robots have been taking jobs at a blistering pace in China," *Fortune*, August 23, 2017.

Automation will displace workers with different educational attainment across a wide range of occupations

Just as there is a wide variation in automation's impact on countries and sectors, so, too, its effect on specific occupations will vary. Those professions highly dependent on the work activities we identified as most susceptible to automation—physical work in a predictable environment, or data collection and processing—are likely to be the most affected, especially if automation adoption occurs earlier, which we anticipate to be the case in countries with high wages such as Japan, Germany, and other advanced economies. By comparison, occupations that require application of expertise, interaction with stakeholders, management and coaching of others, or a high degree of social and emotional response will be less susceptible to automation in the period to 2030.

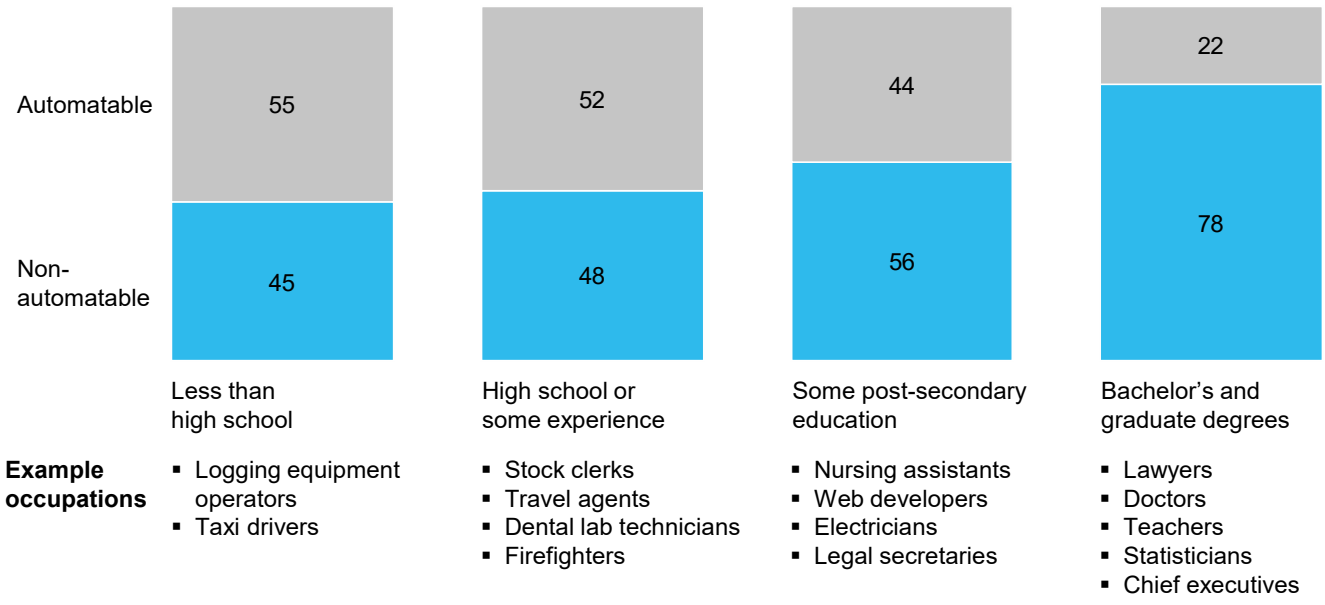
Occupations incorporating significant amounts of physical work in predictable environments including production workers and building and grounds cleaners, as well as office support (such as clerks and administrative assistants), are likely to face significant displacement of their activities by automation, while doctors, health aides, and other care providers and professionals including engineers and business specialists are less likely to experience as much displacement.

The current level of educational requirements for occupations tends to be correlated with the likelihood that their activities can be automated. The technical automation potential for occupations requiring less than a high school diploma is 55 percent, whereas for those with a college degree, that potential is far lower, at just 22 percent. Occupations requiring some post-secondary education generally include work activities that are less automatable than those requiring a high school diploma and some experience, and so on (Exhibit 4).

Exhibit 4

Occupations requiring higher levels of education and experience have lower automation potential

Technical automation potential of work activities by job zone in the United States
%



NOTE: We define automation potential according to the work activities that can be automated by adapting currently demonstrated technology.

SOURCE: US Bureau of Labor Statistics; O*Net; McKinsey Global Institute analysis

Countries and companies have compelling reasons to embrace automation, since the technologies will give a much-needed boost to productivity in the global economy. Depending on the pace of adoption, however, automation technologies in the workplace could displace workers in a wide range of sectors; in our most aggressive scenario for early adoption, almost one-third of work hours in the global economy could be automated by 2030—although other, later adoption scenarios have less dramatic outcomes in that time frame. Economic and social factors beyond technical feasibility affect adoption, and these could lead to strong variations in adoption rates among sectors and countries. Under these circumstances, what will be the future of work? Will the global economy create enough additional jobs to offset those lost to automation, regardless of when adoption takes place? And if so, what sort of jobs will those be, requiring which skills, and paying what wages? In the next two chapters, we highlight findings of our analysis of future labor demand and the complex workforce transitions that automation will likely set in motion.

An automated wool factory in France, circa 1949
© Robert Doisneau/Gamma-Legends/Getty Images

2. LESSONS FROM HISTORY ON TECHNOLOGY AND EMPLOYMENT

For centuries, the arrival of new technology in the workplace has sparked workers' fears—and, sometimes, violent backlash. Already in 1589, England's Queen Elizabeth I refused to grant a patent to a stocking frame invented by William Lee because she was supposedly concerned about the effect on hand knitters.[29] In the early 19th century, textile workers in Britain and France smashed automated looms in their factories and printers struck to protest the arrival of steam-powered presses.[30]

Leading thinkers in the past, from David Ricardo to Karl Marx and John Maynard Keynes, raised concerns about the effect of technological change on employment, and opinion polls show that anxiety has come to the fore again, amid rapid advances in robotics and artificial intelligence.[31] A number of prominent academics and technologists argue that the latest wave of automation technologies, including artificial intelligence and machine learning, will be particularly disruptive to the workforce.[32]

In this chapter, we examine the historical impact of technology on employment, skills, and wages. History does not necessarily repeat itself, but it does provide valuable context and possible lessons for the future of labor demand in a time of automation. Among those lessons are that technological innovation in the past has enabled the creation of many more new jobs than it has destroyed, raising productivity, spurring sustained increases in living standards, and bringing about a shift in the balance of work and leisure. However, the transition has not always been smooth: for example, real wages stagnated for nearly 50 years in 19th century England during the Industrial Revolution there, and only picked up again at a time of substantial social policy reforms. Charles Dickens among other novelists used the harsh realities of everyday life for displaced and other workers as material for his works. History also shows that robust aggregate demand and economic growth are essential for job creation. New technologies have raised productivity growth, enabling firms to lower prices for consumers, pay higher wages, or distribute profits to shareholders. This stimulates demand across the economy, boosting job creation.

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[29] R. L Hills, "William Lee and his knitting machine," *Journal of the Textile Institute*, volume 80, number 2, July 1989.

[30] The most celebrated anti-technology protests were conducted by "Luddites" in Nottingham, England, in 1811, but they were not alone. French textile workers staged an uprising in a silk factory in Lyons in 1831 known as the revolt of the Canuts. Fernand Rude, *La Révolte des canuts 1831–1834*, La Découverte, 2001. A strike by *Times of London* newspaper printers in 1814 linked to the introduction of steam presses was quelled only after the paper's owners promised to keep on printers. Elizabeth L. Eisenstein, *The printing press as an agent of change*, Cambridge University Press, 1980.

[31] Political economist David Ricardo worried in the early 19th century that machines would make labor redundant, while Karl Marx in the 1850s foresaw an era when the means of labor would be transformed by "an automatic system of machinery." In 1930, John Maynard Keynes coined the term "technological unemployment" to describe a situation in which innovation that economized on the use of labor outstripped the pace at which new jobs could be created, in a "temporary phase of maladjustment." David Ricardo, *On the principles of political economy and taxation,* 1817; Karl Marx, *Grundrisse: Foundations of the critique of political economy*, 1858; John Maynard Keynes, "Economic possibilities for our grandchildren," in *Essays in Persuasion*, Macmillan 1933.

[32] Erik Brynjolfsson and Andrew McAfee, *The second machine age: Work, progress, and prosperity in a time of brilliant technologies*, W.W. Norton, 2014,

25

Percentage point decline in share of US agricultural employment between 1880 and 1920

LARGE-SCALE SECTOR EMPLOYMENT DECLINES HAVE BEEN MORE THAN OFFSET BY OTHER SECTORS EMPLOYING WORKERS

Since the First Industrial Revolution began in England in the 18th century, the economies of Europe, the United States, and other countries have undergone two profound waves of structural change. Mechanization enabled a revolution in agriculture and in industry, prompting a migration of workers from the countryside to cities. A second structural shift has occurred in the past 60 years as the share of manufacturing employment has declined in some countries even as growth in service sectors accelerates.[33]

The employment shifts accompanying this process of structural transformation have been very large. In the United States, for instance, the agriculture share of employment declined from 58 percent of total employment in 1850 to 2.5 percent of employment today (Exhibit 5). In just 40 years, between 1880 and 1920, the share of agricultural employment declined 25 percentage points. During the same decades, other sectors were being transformed by mechanization and electrification as well: the share of miners and household workers, for example maids and servants, also declined, although these shifts affected fewer workers. Since 1960, when the second wave of structural transformation began, manufacturing fell from 27 percent of total US employment to 9 percent today, as automation and global trade transformed manufacturing and as demand for services exploded.

The patterns are broadly similar in other countries, although there are some notable differences in the pace. China's shifting sector mix in recent years has been especially rapid: agricultural employment fell as a share of total employment by 32 percentage points in just 25 years, from 60 percent in 1990 to 28 percent in 2015.[34] In Mexico, the agriculture share of employment declined from 52 percent in 1960 to 13 percent in 2015, although in contrast with China, the decline has been gradual and continuous across decades. In Japan, agricultural employment declined from a 31 percent share of total employment in 1960 to 3.5 percent in 2015, while manufacturing's share of total employment dropped from its peak in 1973 of 25 percent to 13 percent in 2015.

Throughout these large shifts of workers across occupations and industries, overall employment as a share of the population has generally continued to grow. New industries and occupations emerged to absorb workers displaced by technology, although as we discuss below, the transition has not always been smooth.

Magnitude of potential job dislocation from automation through 2030 is not unprecedented

When we compare historical sector employment to potential labor displacement from our automation model, we see that even in the earliest automation scenario, future rates of labor displacement from automation within specific sectors are not unprecedented. For example, our analysis shows that a number of sectors in different countries, including agriculture in China, Germany, and Japan, and manufacturing in the United States, have declined by 30 percent and more over a period of 15 years. Our analyses of scenarios of automation displacement over the 15 years from 2016 to 2030 are within the same range (Exhibit 6).

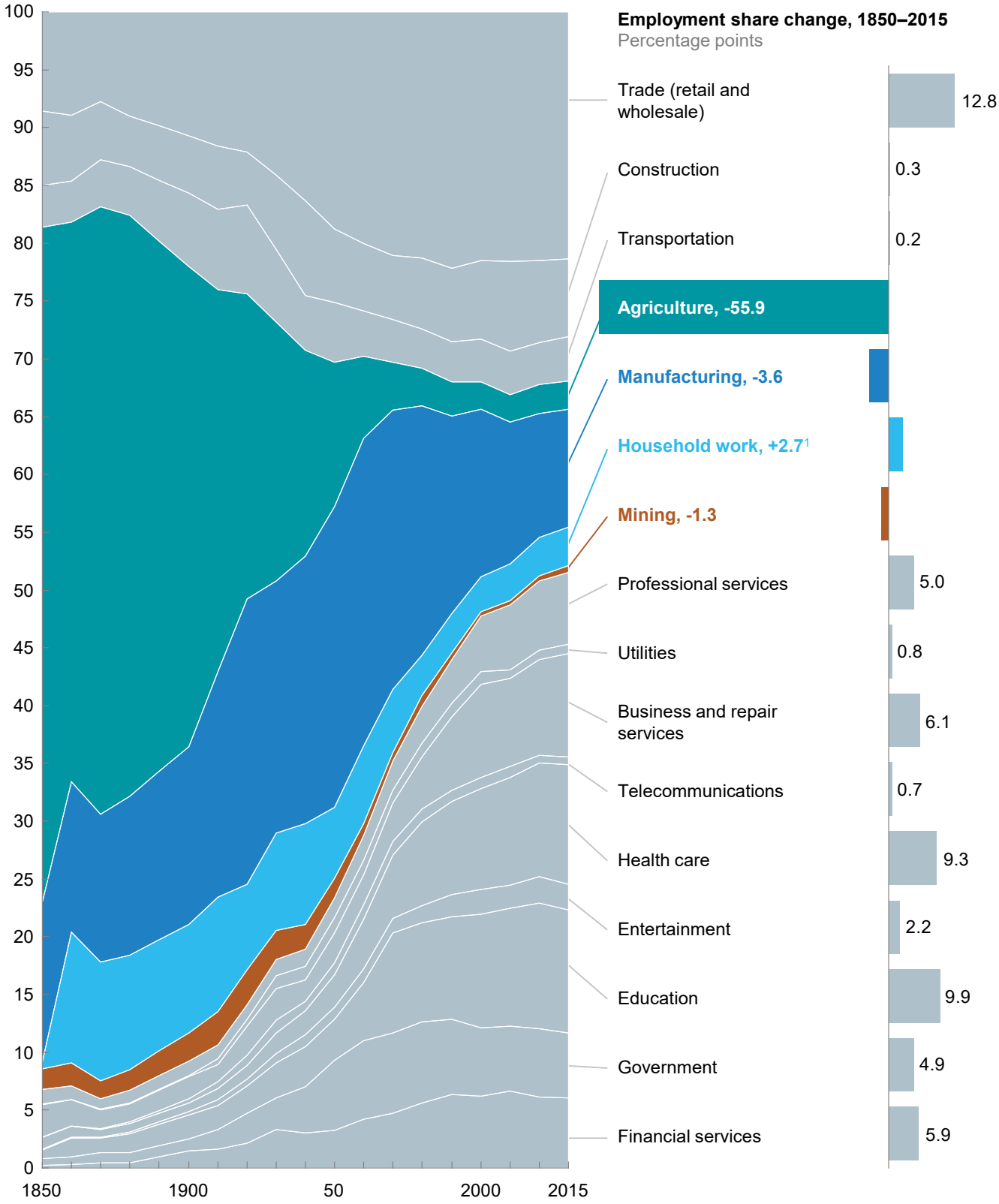
[33] See Berthold Herrendorf, Richard Rogerson, and Ákos Valentinyi, "Growth and structural transformation," in *Handbook of Economic Growth*, Philippe Aghion and Steven N. Durlauf, eds., volume 2, Elsevier, 2014; Benjamin N. Dennis and Talan B. İşcan, "Engel versus Baumol: Accounting for structural change using two centuries of U.S. data," *Explorations in Economic History*, volume 46, number 2, April 2009.

[34] 10-sector database, Groningen Growth and Development Centre.

Exhibit 5

Throughout history, large-scale sector employment declines have been countered by growth of new sectors that have absorbed workers

Share of total employment by sector in the United States, 1850–2015
% of jobs



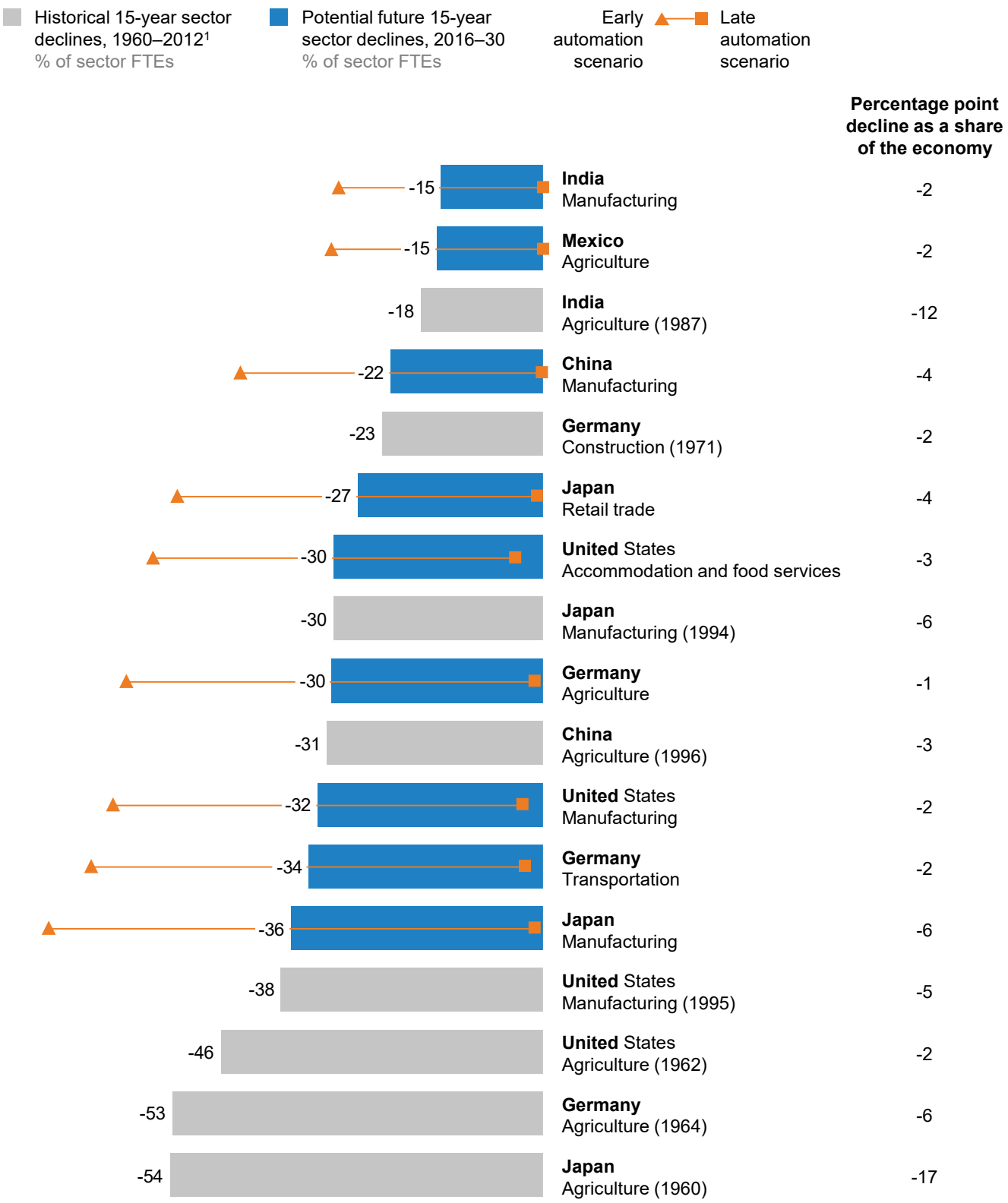
1 Increase from 1850 to 1860 in employment share of household work primarily due to changes in how unpaid labor (slavery) was tracked.

SOURCE: IPUMS USA 2017; US Bureau of Labor Statistics; McKinsey Global Institute analysis

Exhibit 6

Future sector declines from automation are largely expected to be within range of historical declines on a sector basis, but smaller as a share of the overall economy

Selected examples of large sector employment declines vs. potential impact of automation
% decline in sector



1 Sector declines, as a share of the economy, were calculated along a 15-year moving window between 1960 and 2012. Sectors shown here are the largest percentage decline within the 1960-2012 time frame.

SOURCE: Groningen Growth and Development Centre 10-Sector Database; McKinsey Global Institute analysis

TECHNOLOGICAL CHANGE SPARKS RISING PRODUCTIVITY AND AGGREGATE EMPLOYMENT

2x

Growth of female employment in the United States as a proportion of working-age women, from 1950 to late1990s

History shows that the adoption of technological innovation can act as a powerful stimulus on the economy and jobs. The overall effect of mechanization has been to create jobs on an unprecedented scale. Machines allow workers to produce more, thereby raising productivity and (eventually) wages, and lowering the price of goods for consumers. These twin effects unleash new demand for all goods and services. In addition, as firms gain scale, they require more managers, accountants, and other office workers.

This dynamic is the reason that aggregate employment has grown over the long term, even as the size of the workforce has grown. In the United States, for example, female employment almost doubled as a proportion of working-age women from 32 percent in 1950 to 60 percent in the late 1990s before falling back to 57 percent today. Yet this major shift did not reduce overall employment. Indeed, employment grew: the total number of people employed in the United States more than doubled from 65 million in 1960 to 152 million in 2017, according to data from the US Bureau of Labor Statistics. Similar trends have occurred in other countries.

Technology enables productivity growth, raises incomes, and stimulates new consumer demand

Evidence of the economy-wide positive correlation among technology, productivity, and employment can be seen in the aggregate data across countries. Within an industry, machines and automation can sometimes contribute to employment declines. For instance, in the United States, one recent study found that every industrial robot deployed results in the reduction of six human workers within the surrounding metropolitan area.[35] However, when looking at the total economy, we see the opposite effect: rising productivity (often from technology) is usually accompanied by employment growth, not decline. This is because automation raises productivity, which in turn increases incomes of workers and/or shareholders. Higher incomes are spent, creating demand for goods and services across the economy.[36]

When there has been a tradeoff between employment growth and labor productivity growth, it has been short-lived. Looking at the United States since 1960, for example, our analysis shows that employment and productivity both grew in 79 percent of individual years, while productivity grew while employment declined in 12 percent of years. But both employment and productivity grew in 95 percent of rolling three-year periods and 100 percent of rolling 10-year periods. This phenomenon is also seen in other countries. In China, employment and productivity both increased in 77 percent of individual years but 98 percent of the 10-year periods between 1960 and 2016. In Germany, which saw unemployment rise after reunification, employment and productivity grew in 68 percent of individual years but 81 percent of rolling 10-year periods (Exhibit 7).

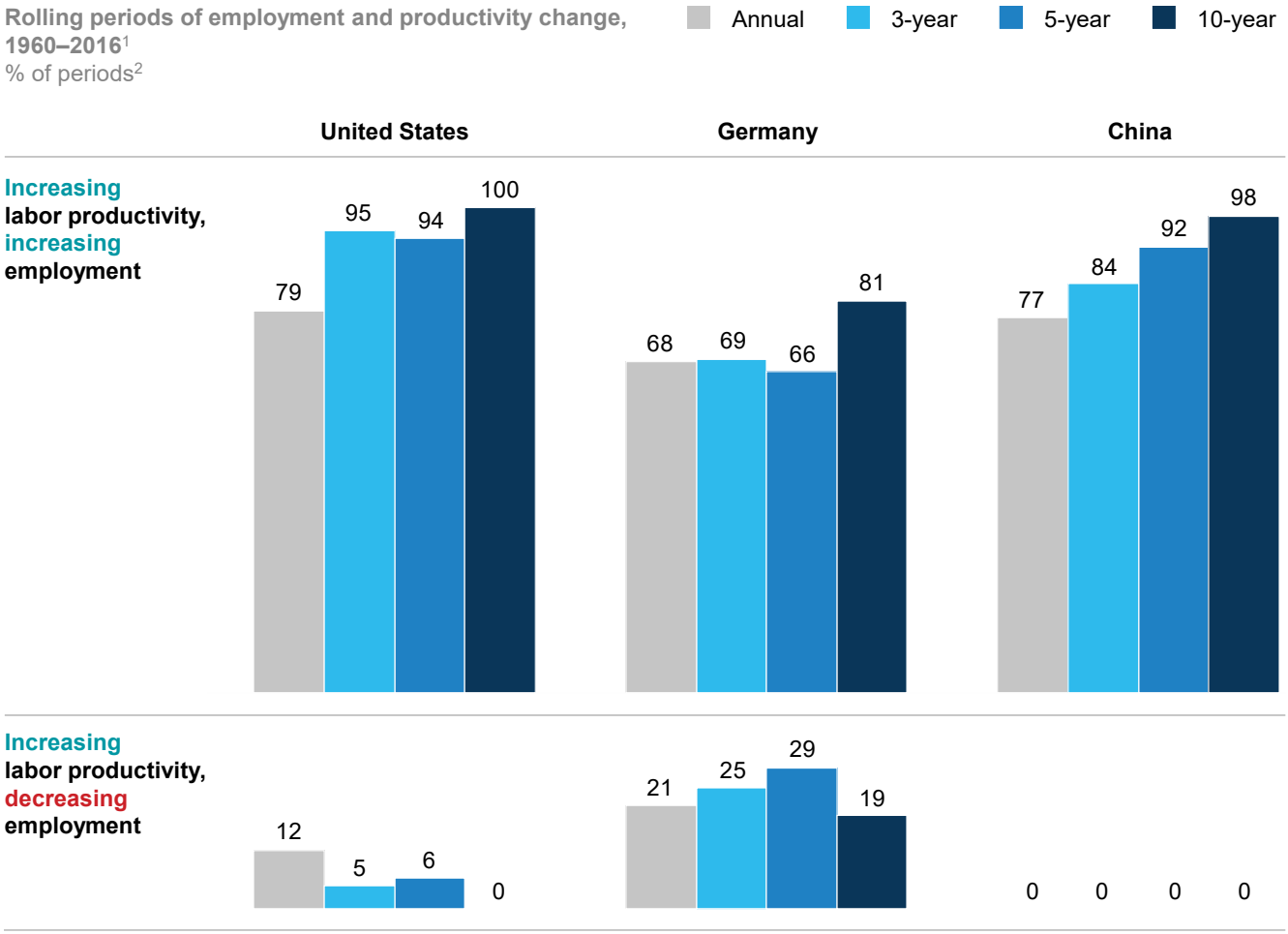
[35] Daron Acemoglu and Pascual Restrepo, *Robots and jobs: Evidence from US labor markets*, NBER working paper number 23285, March 2017.

[36] Ibid. David Autor and Anna Salomons, "Does productivity growth threaten employment?" June 2017.

Exhibit 7

Productivity growth and employment across the entire economy go hand-in-hand—especially when viewed over longer time periods

Rolling periods of employment and productivity change, 1960–2016[1]
% of periods[2]



1 Employment, persons; productivity, GDP per person, 2015 $.
2 Periods categorized into four different scenarios: Increasing productivity and employment, increasing productivity and decreasing employment, decreasing productivity and increasing employment, and decreasing productivity and employment.

SOURCE: The Conference Board Total Economy Database 2016; McKinsey Global Institute analysis

Even as productivity growth leads to rising incomes, technological innovation can also reduce prices and increase the quality of goods and services.[37] This combination can cause demand for a product to soar, resulting in higher employment even within the sector itself. The Ford Model T provides one historical example. The assembly line dramatically improved the productivity of the process of manufacturing automobiles. Exhibit 8 shows that over a six-year period, the number of Model Ts produced per worker annually nearly tripled, from eight to 21. The surge in productivity, combined with increasing economies of scale, enabled Ford to reduce the price from $950 in 1909 to $440 in 1915. As a result, the number of cars sold increased 30-fold, and employment rose from 1,655 to 18,892.[38]

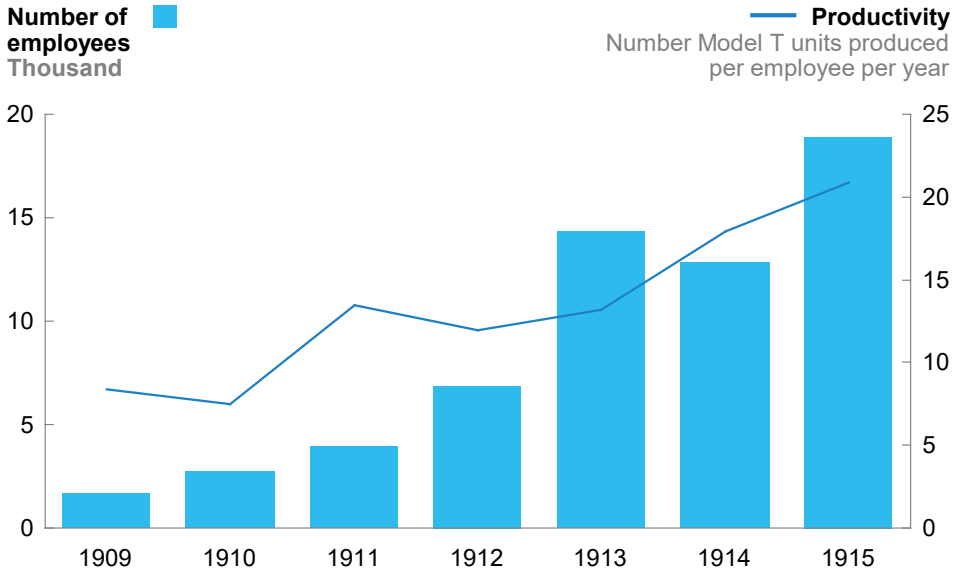
37 Ibid. David H. Autor, "Why are there still so many jobs?" summer 2015.
38 David Hounshell, *From the American system to mass production 1800-1932: The development of manufacturing technology in the United States*, JHU Press, 1985.

Exhibit 8

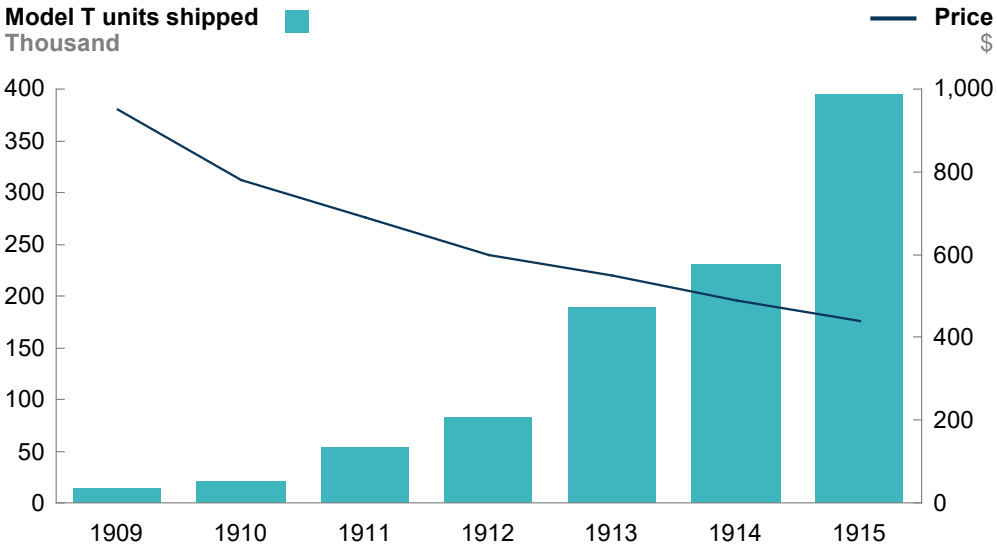
Automation can stimulate employment by lowering the price of a good and unleashing latent demand

Example: Ford Model T assembly line

Assembly line improved productivity and number of employees…



… as prices fell and sales rose



SOURCE: US Bureau of Labor Statistics; FDIC; David Hounshell, *From the American system to mass production 1800–1932: The development of manufacturing technology in the United States*, Baltimore, JHU Press, 1985; Bernard C. Beaudreau, *ICT: The industrial revolution that wasn't*, Lulu, May 2008; McKinsey Global Institute analysis

TECHNOLOGY DISPLACES SOME WORK BUT CREATES NEW JOBS, SOMETIMES IN UNFORESEEN WAYS

It is easy to see which jobs are being destroyed by technology, but difficult to imagine which jobs will be created by it. Telephone switchboard operators have gone the way of lamplighters in the 19th century, but how many of them, lamenting the loss of their jobs, could have imagined the development of the smartphone—and the huge global industry employing tens of millions of people that has sprung up around it? More than 50 years ago, Joseph Schumpeter coined the phrase "creative destruction" to describe this age-old phenomenon in which the emergence of new technology "destroys" jobs by rendering them obsolete, and "creates" new jobs in their wake.[39]

[39] Joseph Schumpeter, *Capitalism, socialism, and democracy*, Routledge, 1942.

Not only does technology create new occupations, it can also change existing occupations in unpredictable ways. After ATMs were introduced in the United States, for example, the number of bank tellers actually rose, as banks competed to provide higher-quality services to customers and the role of tellers changed from dispensing cash to providing broader advice and services. The reduction in the number of tellers per branch enabled banks to open more branches and make retail banking more convenient for customers, which drove the demand for more tellers.[40] From 1991 to 2007, the number of ATMs and tellers in the United States both increased. However, that trend reversed as Internet banking and the 2008 financial crisis resulted in cutbacks in bank branches and tellers.

To better understand the pattern of job creation and destruction, we conducted case studies of two technologies in the United States—personal computers and automobiles—to estimate the number and types of jobs lost to the new technology and the number of new jobs created. In both cases, our research reveals that while some work activities declined, sometimes rapidly, new types of work activities were created. The net impact of both technologies was highly positive, creating new jobs that made up 10 percent of total employment over four decades.

The personal computer enabled the creation of 15.8 million net new jobs since 1980, accounting for 10 percent of employment

Computer-related industries such as computer and data processing services and computer and related equipment manufacturing have been growing rapidly since the 1970s. Microsoft and Apple were founded in that decade. Laptop computers came on the market in the early 1980s, and this century has seen the rapid rise of smartphones and tablets.

The growth of computers has generated significant employment: in the United States, we estimate that computers have enabled the net creation of 15.8 million jobs since 1970 (Exhibit 9). We arrive at this figure by tallying employment gains and losses in different sectors and occupations. We find that in total, we can identify 3.5 million jobs destroyed by the introduction of computers, including those in typewriter manufacturing, secretarial work, and bookkeeping. But at least 19.3 million were created in a wide range of occupations and industries.

When digital editing made it easier and more efficient for authors to type and then directly edit their own work, computers eliminated the need for people specialized in editing and re-typing documents. Employment for typists and secretaries fell significantly, by 1.4 million between 1990 and 2015, even as the overall US workforce grew. The number of bookkeeping clerks also declined, by an annual average of 3 percent in the same period, as accounting moved from physical books to accounting software, resulting in nearly 900,000 fewer jobs.

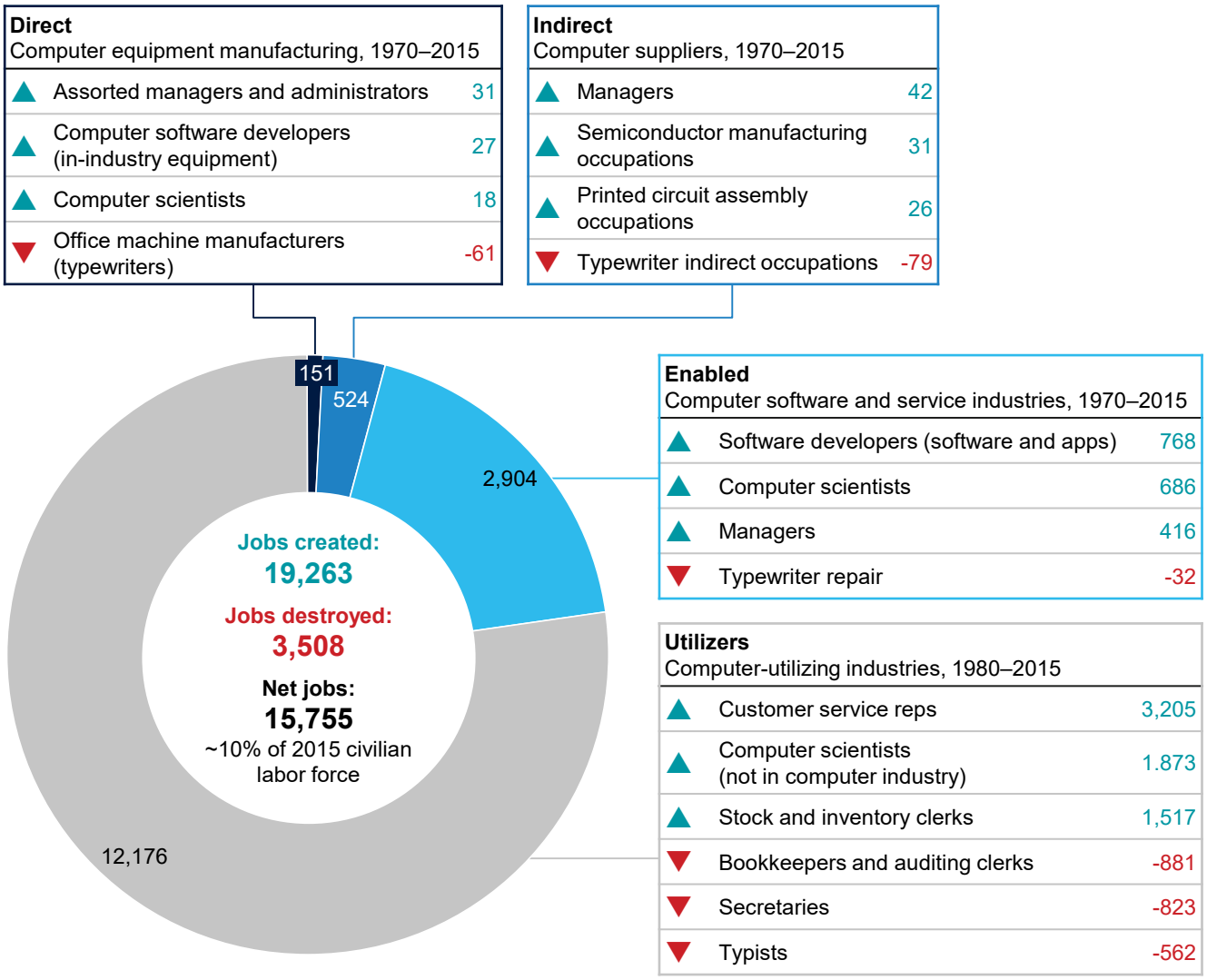
But many new jobs were also created. These include jobs in the computer manufacturing industry and supplier industries (such as semiconductors), as well as employment in occupations enabled by computers (IT systems administrators, computer scientists in other industries), and in occupations that use computers (customer service call centers, which barely existed before computers, and ecommerce). Of this total, only about 1 percent of net new jobs came directly from the computer manufacturing industry and only 3 percent came from supplier industries.

[40] Ibid. James Bessen, *Learning by doing*, 2015.

Exhibit 9

Technology drives the creation of many more jobs than it destroys over time, mainly outside the industry itself

Example: Personal computers
Total US jobs created and destroyed by personal computers (examples listed are not comprehensive)
Thousand jobs



SOURCE: IPUMS; Moody's; IMPLAN; US Bureau of Labor Statistics; FRED; McKinsey Global Institute analysis

A larger share of employment gains has come in professions enabled by computers (18 percent of net employment created). This includes the entire computer software and services industry, with companies such as Oracle, IBM, and Microsoft. This industry employs three million people in the United States, including software and app developers, computer scientists, and managers and office workers.

Because of the multitude of applications of the computer, over 75 percent of net employment generated has been in occupations that use computers. For example, employment of computer scientists in finance, manufacturing, business services, and other industries grew rapidly, by an annual average of about 7 percent, between 1980 and 2015. In the same period, employment of financial managers and specialists able to use spreadsheets to track and analyze large amounts of company data grew by about 3 percent annually on average (see Box 2, "The impact of personal computer and Internet technologies on information analysts").

Box 2. The impact of personal computer and Internet technologies on information analysts

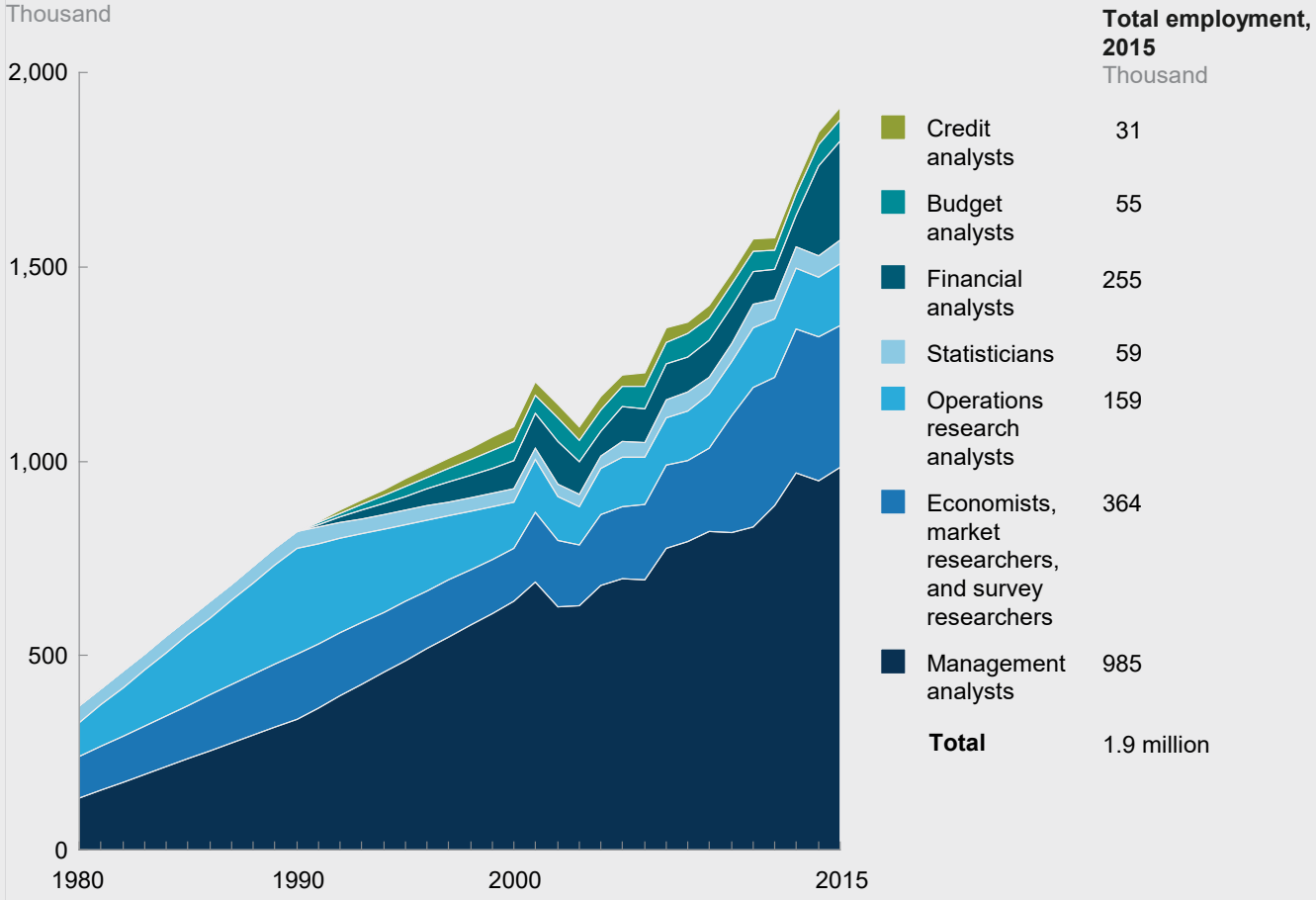
In theory, at least, many information analysts might have been replaced by the rise of the Internet, which makes collecting data and information vastly more efficient, and computers that enable rapid and complex computations. After all, much of their work in the 1980s, before these technologies were widespread, has since been automated.[1]

In fact, the opposite has happened. Computers and the Internet automated activities such as basic mathematics and information gathering, yet the number of information analysts soared nonetheless. As computers became more efficient, the cost of obtaining high-quality information dropped. Rather than decreasing demand for analysts, this stimulated the appetite for more insightful and low-cost analysis, and the number of analysts quintupled from around 400,000 in 1980 to about two million today (Exhibit 10).

The jobs of analysts have changed as well. With information and data more easily accessible, analysts can focus on making sense of—and sharing—information rather than gathering it.

Exhibit 10

The personal computer and Internet might have reduced employment for information analysts, but instead it soared as quality improved



1 Computer, operations, and management analysts were only recorded beginning 1980; credit, financial, and budget analysts were included post-2000.

SOURCE: IPUMS; McKinsey Global Institute analysis

[1] Under information analysts we have included the following Bureau of Labor Statistics occupations: credit analysts, budget analysts, financial analysts, operations research analyst, economists, market researchers and survey researchers, and management analysts.

As computer adoption increased, computer use was correlated with higher wages; employees in these occupations often acquired new skills to use computers, and could demand higher wage premiums.[41] For example, graphic designers took over the jobs of typesetters and started doing a wider range of tasks. Wages increased accordingly as they learned how to use new software and developed higher value skills.[42]

The automobile's largest employment effect has been in enabled industries

The introduction of the automobile created 6.9 million net new jobs in the United States between 1910 and 1950, based on our estimates.[43] This is equivalent to 11 percent of the US workforce in 1950. This includes 7.5 million jobs created, and 623,000 jobs destroyed. Workers displaced by the automobile include manufacturers of wagons, carriages, harnesses and saddles, and of railroad equipment and carriages, as well as supplier industries such as horse breeders and metal work occupations, and enabled industries such as livery services and message boys.

Ten times as many jobs were created in a host of new occupations. About 10 percent were within the auto manufacturing industry (Exhibit 11). Three times as many jobs were in the automotive supply chain, including metal parts manufacturers, warehouses and logistics, and wholesalers. An even larger share of jobs was created in enabled industries and occupations that use the automobile. Enabled industries include auto dealerships, auto repair, gas stations, and convenience stores, and these account for around 30 percent of net new jobs created. Utilizer industries, meanwhile, include transportation and logistics occupations, and account for about 25 percent of employment generated.

If we had extended our analysis beyond 1950, we would have seen the continuing transformative impact of the automobile on the economy and society. Building of the US interstate highway system began in the 1950s, transforming logistics networks. This in turn gave rise to the concept of the "family vacation," long-haul car trips and demand for roadside attractions, motels, and campgrounds. Drive-in movies and restaurants, shopping malls on the edges of towns, and parking lots sprang up. The automobile also enabled growth in suburbs, as workers could commute to jobs from locations outside urban public transportation networks.

THE NUMBER OF HOURS WORKED HAS DECLINED, WHILE LEISURE TIME HAS RISEN

50%
Approximate reduction in working hours in Germany, Sweden, United Kingdom, and United States since 1870

While past technological disruptions did not reduce the amount of work available to people, they nonetheless had one significant effect: a decline in the average number of hours worked per week—and conversely an increase in the amount of leisure enjoyed by individuals. Already in 1930, John Maynard Keynes predicted the advent of greater leisure: "For the first time since his creation man will be faced with his real, his permanent problem—how to use his freedom from pressing economic cares, how to occupy the leisure, which science and compound interest will have won for him, to live wisely and agreeably and well."[44]

In hindsight, Keynes was right: the average number of hours worked each week by employed workers has declined significantly in the past 150 years, giving workers more time for leisure. In 1870, workers in Germany, Sweden, and the United States averaged between 62 and 70 hours each week; in the United Kingdom, which was already shifting

41 James Bessen, *How computer automation affects occupations: Technology, jobs, and skills*, Boston University School of Law, law and economics research paper number 15-49, 2016.

42 Ibid. James Bessen, *Learning by doing*, 2015.

43 Data from Steven Ruggles, Katie Genadek, Ronald Goeken, Josiah Grover, and Matthew Sobek, *Integrated Public Use Microdata Series: Version 6.0* (dataset),University of Minnesota, 2015; Bureau of Economic Analysis; US Census 1900, 1914, 1910.

44 Ibid. John Maynard Keynes, "Economic possibilities for our grandchildren," 1963.

from agriculture to industry, the average worker put in 57 hours per week (Exhibit 12). By 2015, these figures had fallen by roughly half, to around 35 hours in Germany, Sweden, and the United Kingdom and 38.6 hours in the United States. Hours worked have continued to decline as the workforce shifted from manufacturing to services in the past 50 years. In OECD countries, the average hours work declined to 36 hours in 2015 from 42 hours between 1960 and 1980.[45] This trend is especially pronounced in Australia, Denmark, Germany, Ireland, the Netherlands, and Sweden.

Exhibit 11

The automobile created millions of jobs in suppliers and automobile-enabled industries

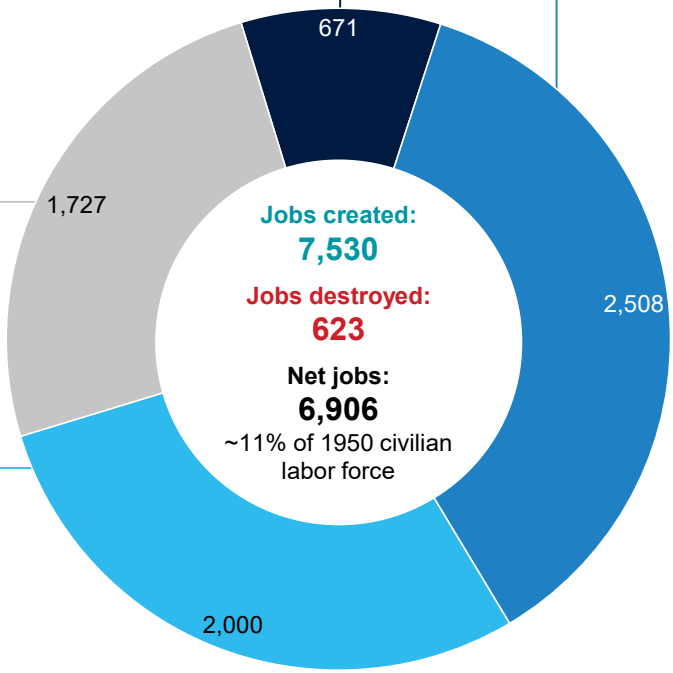
Example: Automotive
Total US jobs created and destroyed by automobiles (examples listed are not comprehensive)
Thousand jobs

Direct: Automobile manufacturing, 1910–50	
▲ Operative and kindred workers	380
▲ Laborers	56
▲ Clerical and kindred workers	55
▼ Railroad and railway occupations	-194
▼ Wagon and carriage factory occupations	-83
▼ Harness and saddle factory occupations	-15

Automobile manufacturing supplier industries, 1910–50	
▲ Primary metals occupations	428
▲ Wholesale trade occupations	233
▲ Transportation and warehousing	220
▼ Textile mills occupations	-13
▼ Primary metals occupations	-13
▼ Transportation and warehousing occupations	-12

Automotive-utilizing industries, 1900–50	
▲ Truck and tractor drivers	1,241
▲ Deliverymen	154
▲ Mail carriers	128
▼ Messengers and office boys	-24

Automotive-enabled industries, 1910–50	
▲ Automobile mechanics	533
▲ Managers (e.g. dealerships, service centers)	452
▲ Automotive service and parking attendants	253
▼ Rail equipment	-150
▼ Livery stable industry	-34



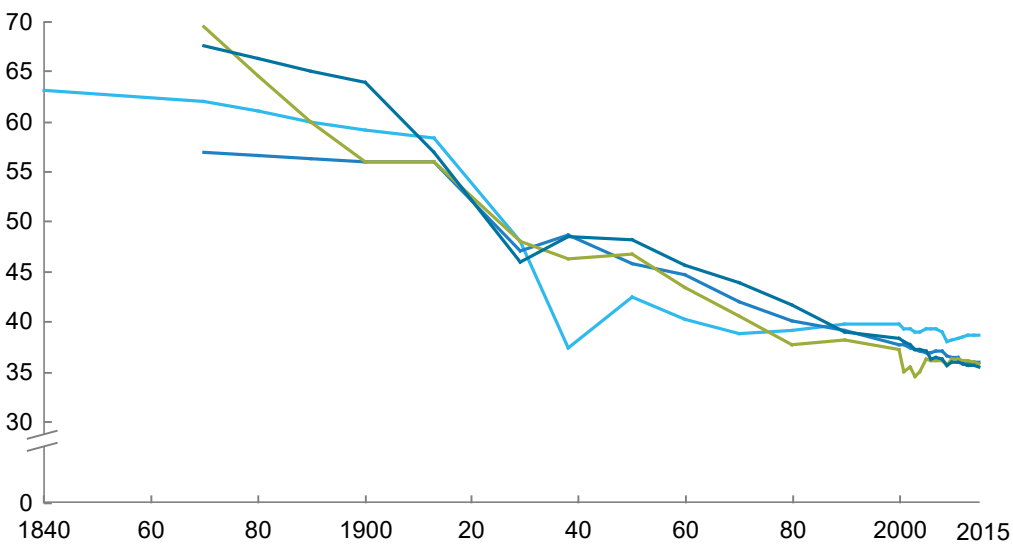
SOURCE: IPUMS; Moody's; IMPLAN; US Bureau of Labor Statistics; FRED; McKinsey Global Institute analysis

[45] Jeremy Reynolds, "You can't always get the hours you want: Mismatches between actual and preferred work hours in the U.S.," *Social Forces*, volume 81, number 4, June 2003; Michael White, *Working hours: Assessing the potential for reduction*, International Labour Organization, December 1987; Robert E. Hall, *Wages, income and hours of work in the U.S. labor force*, Massachusetts Institute of Technology, working paper number 62, August 1970.

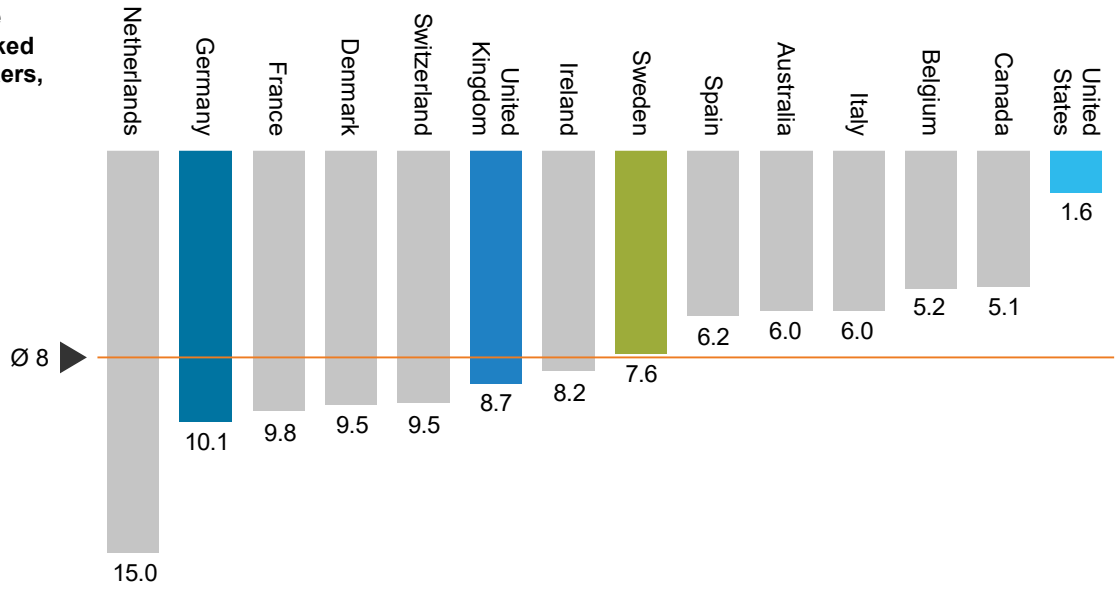
Exhibit 12

Average hours worked weekly have declined sharply since the mid-1800s

Average hours worked weekly by employed workers, 1840–2015



Decline in average weekly hours worked by employed workers, 1960–2015



NOTE: These workweek numbers take into account paid time off and holidays.

SOURCE: Michael Huberman and Chris Minns, "The times they are not changin': Days and hours of work in Old and New Worlds, 1870–2000," *Explorations in Economic History, 2007*; ILO; US Bureau of Labor Statistics; ONS Labor Force survey; McKinsey Global Institute analysis

The decline in average hours worked reflects the productivity improvements that have compounded over the years, allowing people to work less per week and yet still support growing economies. Differences between countries reflect different labor policies and social institutions governing the number of expected hours of work per week and vacation days. In the early 20th century, labor unions in the United States and in Europe pushed for national policies to cap the work week at 40 hours (which eventually became an International Labour Organization standard). In European countries such as France and Germany, a second wave of working-hour reductions took place in the 1980s and 1990s; in France, the government lowered the official work week to 35 hours—and today there is some evidence

that French people would work more if they could.[46] Since 1960, the total hours worked has declined by 26 percent in Germany, 8 percent in Italy, and 7 percent in France.

The decline in average hours worked also reflects the steady rise of part-time employment across countries. The highest proportion of part-time work is in the Netherlands (39 percent of employed persons), the United Kingdom (24 percent), and Germany and Japan (22 percent).[47] Part-time work is often preferred for a variety of reasons by students, caregivers, and people nearing retirement, but also by some employers in markets where rigid labor market policies make full-time hiring economically unattractive. In the past decade, the number of people in the United States and Europe who earn money in the independent workforce—as freelancers, independent contractors, self-employed, and workers in the "gig" economy—has grown, to an estimated 162 million.[48] Many of these individuals work less than a full-time schedule.

As leisure time increases, people spend money on hobbies, entertainment, and other personal services, giving rise to entire new industries that in turn create jobs. Skiing, golfing, tourism, crafting, and do-it-yourself home projects are a just a few industries that have sprung from the new leisure economy. The number of jobs involved is significant: globally, as many as 292 million people are employed directly or indirectly by tourism—one in every ten jobs on the planet.[49]

THE IMPACT OF TECHNOLOGICAL CHANGE ON WAGES AND SKILLS

For some English workers during the early 19th century, wages stagnated or fell for

50 YRS

Adjusting the economy to new technological disruptions may take time, and can have significant repercussions for both skills and wages. In the first half of the 19th century, during the First Industrial Revolution in England, the steam engine and other technologies increased the productivity of unskilled workers and enabled them to undertake work previously carried out by higher-skill, and higher-paid, workers including craftsmen and artisans. Across the economy, mechanization raised output per worker. However, real wages stagnated for roughly 50 years, from 1790 until 1840 (Exhibit 13). During this period, first noted by economist Friedrich Engels in 1845, profits as a share of national income rose and the labor share of income declined.[50] After 1850, real wages began rising in line with productivity increases, and by the late 1800s wage growth exceeded productivity growth. But for nearly half a century, wage growth was nil and real living standards of workers declined. The plight of some workers provided material for Charles Dickens's bleak depictions in his novels, and led the English poet William Blake to decry factories as "dark, satanic mills."[51] The turnaround in the relationship between wages and output came at a time of substantial reform of existing structures including the right to unionize, limitations on

[46] An MGI survey of 16,000 Europeans in eight countries showed that a majority was willing to make tradeoffs, including working more hours per week in exchange for more income and better services. This willingness to increase working hours was especially pronounced in France, where the workweek was officially lowered to 35 hours from 2000. *A window of opportunity for Europe*, McKinsey Global Institute, June 2015.

[47] Arne L. Kalleberg, "Nonstandard employment relations: Part-time, temporary and contract work," *Annual Review of Sociology*, volume 26, August 2000; Chris Tilly: "Reasons for continuing growth of part-time employment," *Monthly Labor Review*, March 1991; Rachel A. Rosenfeld and Gunn Elisabeth Birkelund, "Women's part-time work: A cross-national comparison," *European Sociological Review*, volume 11, number 2, September 1995.

[48] Our research has found that 20 to 30 percent of the working-age population in the United States and Western Europe works independently, including many who do so part-time. The majority, 70 percent, say they do so out of choice, with the remainder doing so out of necessity. *Independent work: Choice, necessity and the gig economy*, McKinsey Global Institute, October 2016.

[49] *World economic impact*, World Travel and Tourism Council, 2017.

[50] Ibid. Robert Allen, "Engels' pause," October 2009; for a discussion of historical wage trends, see also Gregory Clark, "The condition of the working class in England, 1209-2004," *Journal of Political Economy*, volume 113, number 6, 2005.

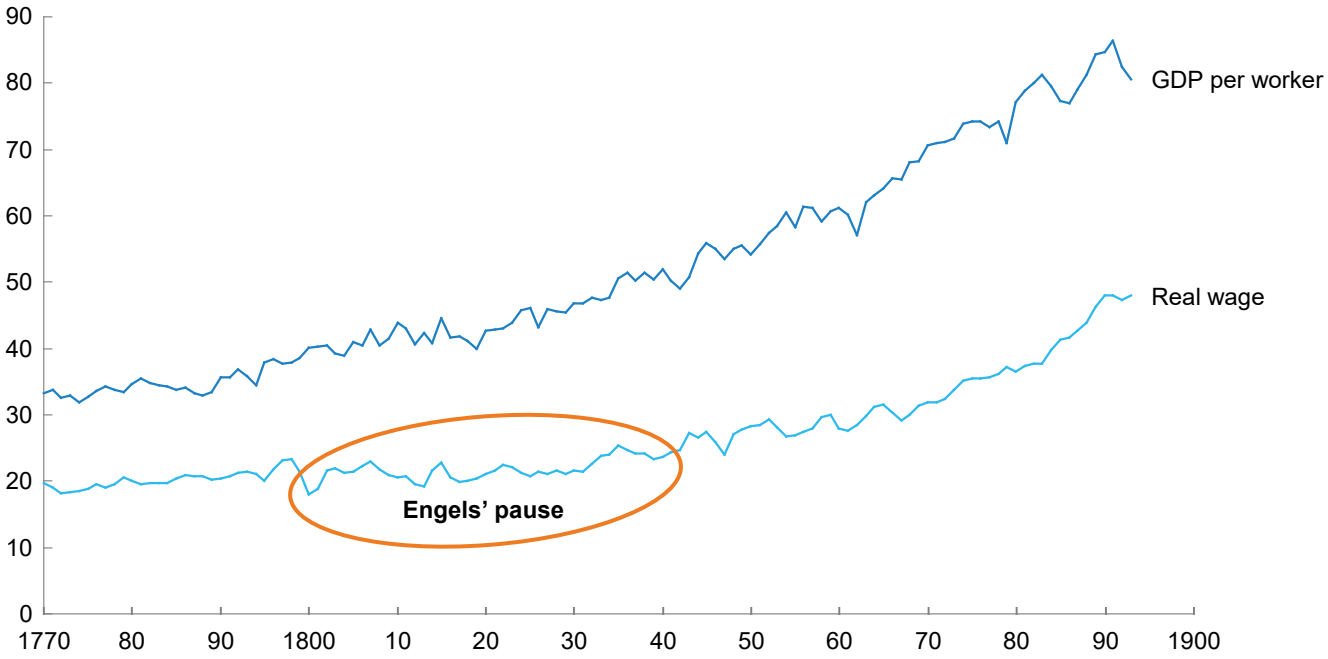
[51] Dickens's novels painting a stark picture of everyday life in Victorian England include *Oliver Twist* (1838) and *Hard Times* (1854). The line about dark, satanic mills is in William Blake's poem "And did those feet in ancient time," from the preface to *Milton: A Poem, 1804*.

child labor, the introduction of public high schools, urban planning to improve public health, elimination of debtors' prison, and the extension of the right to vote to landless workers.[52]

Exhibit 13

Engels' pause shows that during the Industrial Revolution, UK wages stagnated despite accelerating productivity growth

UK historical real wage vs. GDP per worker, 1770–1893
1851 real £ per year



SOURCE: Robert C. Allen, "Engels' pause: Technical change, capital accumulation, and inequality in the British industrial revolution," *Explorations in Economic History*, volume 46, issue 4, October 2009; McKinsey Global Institute analysis

The growing mechanization led to a shift in the skills of the workforce and affected semi-skilled artisans negatively. Economic historians have documented the consequences for previously well-paid workers such as hand-loom weavers, whose income tumbled in the 1820s, leading to immiseration of many, even as the invention of automated looms lifted other, unskilled workers out of poverty.[53] At the same time, the share of unskilled labor in the British workforce increased, from 20 percent in the late 16th century to nearly 40 percent in the early 19th century.[54] This "deskilling" of the workforce occurred in agriculture and industry alike, prompted by land concentration that enabled mechanized agriculture and the shift from artisans' workshops to factory production in industry. During this period there was also some growth in the share of skilled workers such as machine erectors and operators, who were needed to facilitate the Industrial Revolution.

More recently, academic research shows that local labor markets, including in the United States, have taken years to adjust to trade shocks from competition from China, with wages and labor-force participation rates remaining depressed and unemployment rates remaining elevated for at least a full decade after the trade shock started.[55] Some research also

[52] Peter Mathias, *The first industrial nation: The economic history of Britain 1700–1914*, Routledge, 2001.

[53] Robert C. Allen, *The hand-loom weaver and the power loom: A Schumpeterian perspective*, University of Oxford, discussion papers in economic and social history, number 142, March 2016.

[54] Alexandra M. de Pleijt and Jacob L. Weisdorf, "Human capital formation from occupations: The 'deskilling hypothesis' revisited," *Cliometrica*, volume 11, number 1, January 2017.

[55] David H. Autor, David Dorn, and Gordon H. Hanson, *The China shock: Learning from labor-market adjustment to large changes in trade*, NBER working paper number 21906, January 2016.

suggests that increasing structural unemployment of non-college US whites of the past two decades—driven by automation and offshoring in manufacturing, among other things—may have contributed to rising morbidity rates.[56]

Whether the experience of technological disruption in the past is relevant for economies in the future can be debated. In Chapter 4 of this report, we present new analysis of the impact of automation today on the demand for different types of skills and discuss the potential impact on wages. Even if the particulars of the historical experience turn out to differ from conditions today, one lesson seems pertinent: although economies adjust to technological shocks, the transition period is measured in decades, not years, and the rising prosperity may not be shared by all.

AUTOMATION TODAY: COULD THIS TIME BE DIFFERENT?

Despite the reassuring lessons from history on the long-run impact of automation on employment, some technology experts argue that automation today will not behave like previous technology waves. They cite a number of reasons that the future may bring more disruption to workers than in the past, including the ability of machines to perform work activities requiring cognitive capabilities, the rate of progress in new innovations, and a potential future in which machines teach themselves to improve at particular tasks without much human intervention.[57] Many economists, however, tend to view automation as the next wave of technological advancement and point out that an equilibrium between the supply and demand of jobs in labor markets has always been reached historically, even if the transition period may be difficult.[58]

In part, the discord between the two points of view may be caused by the lack of a common language: what exactly could be different about automation compared with previous technologies? What time frame are we considering? In our research we looked at a range of arguments on both sides and examined the evidence for both the scope of automation's impact and its nature across multiple dimensions. This framework is useful for disentangling the different elements of technological disruption and assessing the ways in which today's technology may—or may not—have a different impact than in the past.

We conclude that in many respects, the impact of automation on employment today is not likely to be different than in the past, particularly if we look back centuries, to the First Industrial Revolution in the late 1700s. But we have identified two ways in which automation, robotics, and AI could diverge from earlier waves of technology disruption: the speed at which scientific advances are being made, if the accelerated rate of progress in machine learning and AI continues, and the potential to displace a higher share of the workforce in a relatively short period of time, particularly if the adoption of automation is rapid across multiple sectors of the economy.

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[56] Anne Case and Angus Deaton, "Rising morbidity and mortality among white non-Hispanic Americans in the 21st century," *Proceedings of the National Academy of Sciences of the United States of America*, volume 112, number 49, December 2015.

[57] See for example the 2017 public debate between Tesla CEO Elon Musk and Facebook CEO Mark Zuckerberg over artificial intelligence and the threat that it may or may not pose to mankind. Ian Bogost, "Why Zuckerberg and Musk are fighting about the robot future," *The Atlantic*, July 27, 2017. See also, Rafi Khatchadourian, "The Doomsday invention," *The New Yorker*, November 23, 2015.

[58] Christopher Pissarides and Giovanna Vallanti, *Productivity growth and employment: Theory and panel estimates*, Center for Economic Performance, discussion paper number 663, December 2004; Jason Furman, "Is this time different? The opportunities and challenges of artificial intelligence," remarks at AI Now: The Social and Economic Implications of Artificial Intelligence Technologies in the Near Term conference in New York, July 7, 2016.

Rate of technological innovation

Could be faster than the past

In Chapter 1 we noted the rapidity of recent technological innovation as a result of the development of deep learning and reinforcement-learning techniques based on neural networks; the availability of exponentially increasing computing capacity that is accessible to users via the cloud; and the sheer volume and variety of data generated that can be used to train machine learning models. Advocates of the argument that automation today is fundamentally different in its scope point to this acceleration of innovation as evidence of a real break with the past.

Those who disagree, however, point to Moore's Law, named for Gordon Moore, a co-founder of Intel, who in 1965 noted that the number of transistors incorporated in a computer chip would approximately double every 24 months—which became the basic business model for the semiconductor industry for the following decades.[59] The shrinking of transistors in semiconductors improved computing speed and capacity and helped usher in the internet era, as well as the mobile phone revolution and the cloud. However, the rate of progress in shrinking transistors has slowed, and some scientists project that without a new computing model, future advances may run out. Moreover, AI veterans point to previous eras when what seemed to be fast-moving advances in AI gave way to frustrating lulls. AI dates back to the 1950s, when Alan Turing suggested that computers could communicate as well as humans and Princeton students including Marvin Minsky and Dean Edmonds built the first artificial neural network using 300 vacuum tubes and a war-surplus gyropilot. After the initial excitement, funding slumped in the 1970s as research backers—primarily the US government—tired of waiting for practical AI applications and cut appropriations for further work. Another lull followed in the 1990s.[60]

Our view is that the recent technical advances, enabling machines to read lips or X-rays more proficiently than human experts, are indeed remarkable and that if this pace of innovation continues rather than encountering a new AI "winter," the rate of automation innovation could indeed be faster than in the past. If so, the potential disruption of workforce models and displacement of labor could be greater than past technological revolutions.

Rate of technological adoption

Faster than 100 years ago, but no evidence of acceleration in recent decades

Even if technological innovations are occurring more rapidly, the impact on workers will be different only if the diffusion and adoption of new technologies also accelerates. Some researchers say this is the case, pointing to examples such as landline telephones, electrification, or the automobile. Indeed, while it took almost a century for landline phones to reach saturation, or the point at which new demand falls off, mobile phones in some markets reached that point in just 20 years and smartphones in even less time.[61] One commonly found reference is the speed with which certain online videos on YouTube or smartphone games such as Angry Birds or Pokemon Go reach a certain threshold of downloads—50 million, 100 million, or more.[62] Based on measures of gross numbers, for example, of people adopting a technology, you could say that adoption rates have accelerated. However, it is also worth considering adoption rates when measured using percentages.

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59 "Moore's law and Intel innovation," Intel, https://www.intel.com/content/www/us/en/history/museum-gordon-moore-law.html

60 Michael Negnevitsky, *Artificial intelligence: A guide to intelligent systems*, Addison-Wesley, 2002. See also, *Artificial intelligence: The next digital frontier?* McKinsey Global Institute, June 2017.

61 Michael De Gusta, "Are smart phones spreading faster than any technology in human history?" *MIT Technology Review*, May 9, 2012; Gisle Hannemayr, The Internet as hyperbole: A critical examination of adoption rates, https://hannemyr.com/en/diff.html.

62 Stanford University Infolab, Stanford University, infolab.stanford.edu.

Looking at only the last 60 years, our review of the historical rates of adoption of 25 previous technologies shows that the time from commercial availability to 80 percent adoption has tended to fall within a relatively constant range: between approximately eight and 28 years. For 50 percent adoption, the range is five to 16 years. The technologies reviewed date back to TVs in the 1950s, and include recent examples of cell phones, customer relationship management software, and lithium-ion cell batteries. This range of times for adoption was observed for both hardware-based technologies that are capital-intensive and require physical installation; and technologies that are available purely online. Technologies with the fastest adoption rates include stents, airbags, MRIs, TVs and online air booking, while slower adoption categories include dishwashers and pacemakers from the 1960s, and cellphones in the 2000s. Even highly popular and widely-used social media applications do not achieve a high level of adoption faster than technologies in previous eras. Facebook is one example: it was launched in 2004 and quickly achieved worldwide success. Yet even by mid-2016, when it had about 1.7 billion users globally, it was still far from full adoption, even outside China.[63] Moreover, it was not the first social network, and so the adoption period could be calculated as being even longer—since the advent of the first modern social network, Six Degrees, which launched in 1997, or Classmates.com, which launched in 1995.[64]

Our view is thus that there is no evidence that technological adoption has yet accelerated over the last 60 years, when measured in percentages, although, not surprisingly, diffusion is faster than it was for technologies introduced in the early 20th century.

Breadth of sectors in which work can be automated

Not different from the past

Some commentators say that today's automation is different from the past because it has the potential to transform work in multiple sectors simultaneously. They argue that the largest technological disruptions of the past have been the move out of agriculture or, more recently, from manufacturing into services. Advocates of the "this time things are different" argument point to the pervasiveness of automation technologies as being different, in that they will affect multiple sectors of the economy—from finance to retail to manufacturing to transportation—simultaneously.[65]

As points of comparison, one can consider the application of some technologies in the past, such as electricity or computers, which also transformed work across multiple sectors of the economy simultaneously. Electrification transformed household lighting, heating, and refrigeration; it enabled stores and factories to open for longer hours; and it gave birth to mass production. Similarly, computers transformed business services, finance, and retail and gave birth to the Internet and mobile computing. The steam engine drove the Industrial Revolution, upending numerous sectors from weaving to printing, for example. Between 1910 and 1950, successive waves of innovation also proved highly pervasive, from automobiles to assembly lines.

Our view is that little is new about the breadth of impact of automation technologies.

Share of jobs in the economy that be automated by 2030

Could be higher than past technologies if adoption is rapid

Even if past technological innovations transformed work in multiple sectors of the economy, today's automation could affect a larger share of work. Proponents of this view point out that some sector employment shifts have been extremely large—for example, the rapid transitioning out of agricultural employment in China, or the steep decline in US agriculture in

[63] Internet World Statistics.

[64] Danah M. Boyd and Nicole B. Ellison, "Social network sites: Definition, history, and scholarship," *Journal of Computer-Mediated Communication*, volume 13, number 1, October 2007; Classmates.com.

[65] Rudina Seseri, "The AI disruption wave," *TechCrunch*, October 13, 2016.

the 20th century. The potential impact on demand for current work activities in some sectors as a result of automation today could likewise be very large. Viewed over a 15-year period, our automation model suggests that roughly half of the existing work in countries such as Germany, Japan, and the United States could be displaced by 2030 if automation adoption is at the most rapid end of our modeling. In the past, also looking at 15-year periods, our analysis shows that as much as 30 percent of jobs were displaced in historical episodes—in other words, lower than our most rapid automation scenario but not of a completely different order of magnitude.

Our view is thus that, if automation adoption is very rapid, it could potentially displace a greater percentage of work in some advanced economies in the next 15 years than we have seen in the past.

Types and complexity of tasks that can be automated

Every wave of automation affects more complex tasks

Alongside the scope of automation's impact, its very nature has sparked discussion about differences between technological change today and in the past. One frequently-cited argument concerns the type of tasks that AI in particular now can accomplish with prowess, from driving trucks to creating music and art to playing championship Go. The power of algorithms to take on activities requiring cognitive capabilities and creativity is held up as a fundamental break with previous technologies.[66]

Skeptics point out, however, that this is not the first time that machines have been able to carry out tasks requiring cognitive capabilities. Every new wave of automation seems remarkable at the time. From the 1980s, with the birth of computerized spreadsheets, machines have taken on ever more sophisticated tasks that previously required human brainpower, from manipulating large quantities of data and alphabetizing lists or doing complex calculations to anticipating the words your fingers are about to type on a smartphone. While the tasks themselves have changed, our view is that the ability of machines to acquire such capabilities is not in itself new. While significant progress has been made in specific "narrow" AI applications, formidable multi-decade-long technological challenges must still be overcome before machines can match human performance across the range of cognitive activities and approach "artificial general intelligence"—which would indeed be a break with historical precedent.

Skill bias of technical change

Today's automation could complement both high- and low-skill workers

Technological innovation has affected workers in different ways in the past. As already noted, the steam engine and other technologies introduced during the Industrial Revolution in Europe and the United States in the 19th century increased the productivity of unskilled or low-skill workers and enabled them to undertake work previously carried out by high-skill, and higher-paid, workers including artisans such as hand-loom weavers. In the academic literature, technological change was thus considered to be biased toward enabling low-skill workers at the expense of high-skill ones.

In our era, the opposite has happened: computers and factory-floor robots have tended to increase the productivity and complement the work of high-skill workers, while machines have substituted for the programmable and routine tasks that had been undertaken by low-skill workers, including those working on assembly lines or as switchboard operators.[67]

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[66] See, for example, the interview with Andrew Ng and Neil Jacobstein,"How artificial intelligence will change everything," *The Wall Street Journal*, March 6, 2017.

[67] David H. Autor, Frank Levy, and Richard J. Murnane, "The skill content of recent technological change: An empirical exploration," *The Quarterly Journal of Economics*, volume 18, number 4, November 2003; David Hounshell, *From the American system to mass production 1800-1932: The development of manufacturing technology in the United States*, JHU Press, 1985.

This is known as skill-biased technical change. Some economists view the effects of technological change and technology-enabled globalization in recent decades as a significant driver of inequality.[68]

We do not have firm evidence yet on whether automation today will tend to be more skill-biased or unskill-biased in its impact. Our analysis of how automation will affect skills, detailed in Chapter 4, suggests that workers of all skill and educational levels will be affected. Some technologies might enable lower-skill workers to replace higher-skill ones—such as nurses who can perform some of the more routine tasks of doctors with the aid of diagnostic tools. Other technologies will complement high-skill workers and enable them to command even greater power in the marketplace—for instance surgical robots or AI algorithms that can suggest new investment strategies.

Impact on high-wage vs. low-wage work

Both will be affected

A final dimension on which technological change could be different today is its impact on workers at different wage levels. One of the frequently-cited concerns about automation is that machines could replace activities of high-wage jobs previously considered "safe," including experts in financial services, some types of doctors, and lawyers.

While our analysis of automation's impact on wages, also in Chapter 4, suggests that a range of high-wage occupations could be affected, there is ample historical precedent for this, including the hand-loom weavers in 19th-century England who suffered a steep decline in their livelihoods after the arrival of mechanized looms, which allowed lower-wage and lower-skill workers to produce more cloth, faster, and less expensively.[69] We therefore conclude that today's automation is unlikely to be different from the past on this dimension.

•••

In 1930, at the height of the Great Depression, John Maynard Keynes wrote, "We are suffering, not from the rheumatics of old age, but from the growing-pains of over-rapid changes, from the painfulness of readjustment between one economic period and another." As many do today, he saw the speed of technological change as something formidable, an era of progress and invention incomparable to any that had come before—yet also as a time of painful transition for many. In the 1960s, a US national commission on technology, automation, and economic progress established by President Lyndon B. Johnson concluded that, "the basic fact is that technology eliminates jobs, not work. It is the continuous obligation of economic policy to match increases in productive potential with increases in purchasing power and demand. Otherwise, the potential created by technical progress runs to waste in idle capacity, unemployment, and deprivation."[70] The question for us today is whether, this time, the transitions will be larger and more painful than ever, and indeed how demand for human labor will evolve. In this chapter, we have described the historical evidence showing that employment remains strong even in periods of technological ferment. In the following chapters, we look at the trends that can create demand for tens of millions of new jobs in the global economy over the next decade and more, even as robotics and AI increasingly make their way into our daily work lives, and what the implications will be for sectors, occupations, skills, and wages.

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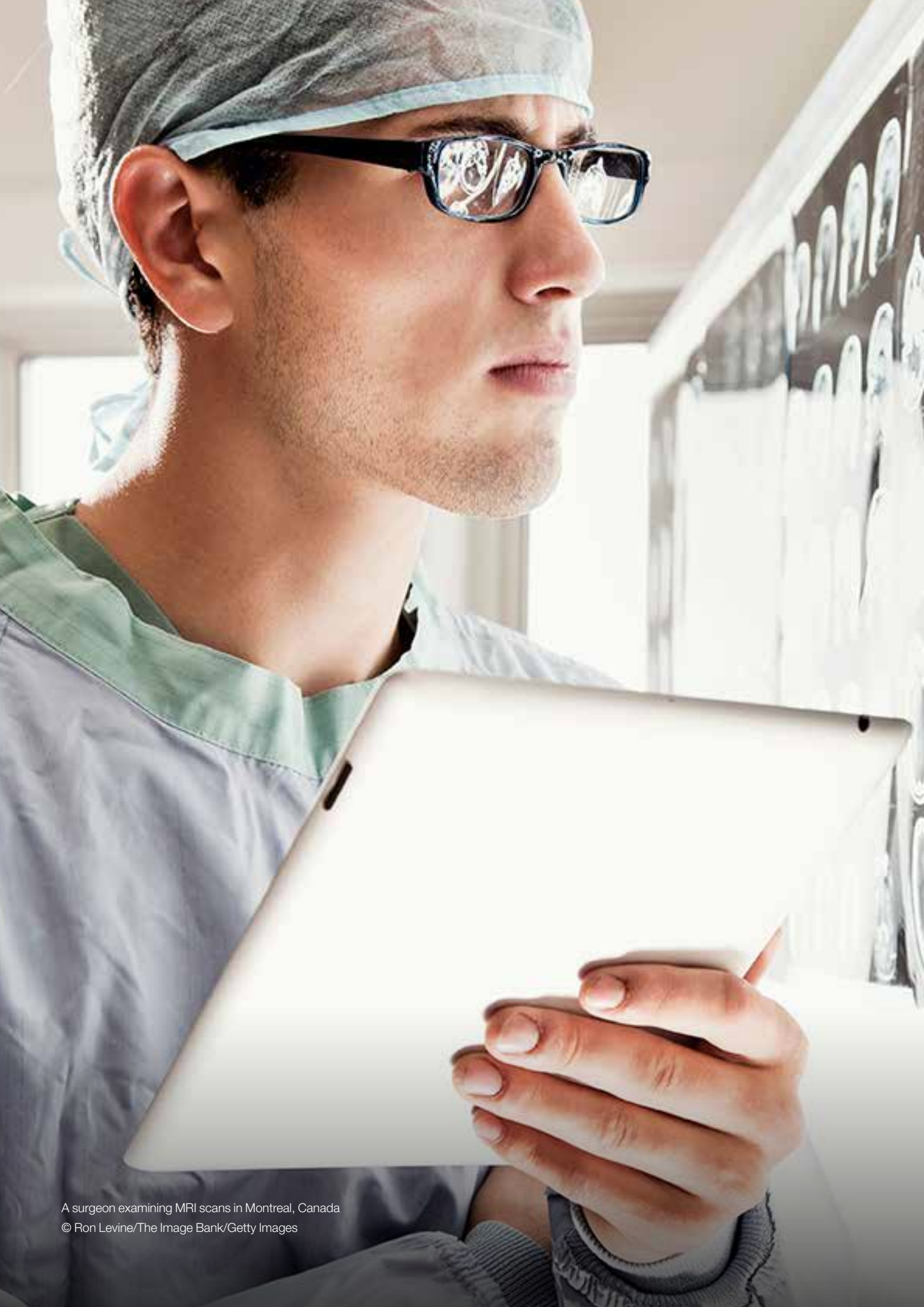
[68] Laura Tyson and Michael Spence, "Exploring the effects of technology on income and wealth inequality," in *After Piketty: The agenda for economics and inequality*, Heather Boushey, J.Bradford DeLong, and Marshall Steinbaum, eds, Harvard University Press, May 2017.

[69] Ibid. Robert C. Allen, *The hand-loom weaver and the power loom*, March 2016.

[70] *Technology and the American economy: Report of the National Commission on Technology, Automation, and Economic Progress*, US Department of Health, Education, and Welfare, February 1966.



A surgeon examining MRI scans in Montreal, Canada
© Ron Levine/The Image Bank/Getty Images

3. JOBS GAINED: SCENARIOS FOR EMPLOYMENT GROWTH

While automation will displace some workers and transform occupations, we also know that new and additional work will be created in the next decade and beyond. What is less clear is how job growth net of automation will vary by occupation, and under what conditions there will be enough new jobs to offset the work that is lost as robotics, artificial intelligence, and other technologies assume a greater role in the workplace. Predicting all the jobs that will exist in the future is an impossible task, yet even without a crystal ball, it is possible to identify some sources of future labor demand.

In this chapter, we discuss two different analyses that shed light on these questions. To understand some of the occupations and types of jobs likely to be in demand in 2030, we model seven specific global trends that we expect will be significant drivers of job creation. To inform the impact of automation on aggregate employment, we conduct a second analysis using the McKinsey Global Growth Model, which is a multi-country macroeconomic model. This exercise allows us to model the dynamic effects of automation on productivity, employment, and GDP growth in different scenarios. Automation has the potential to raise productivity growth and GDP growth, but our analysis reveals that a key factor in whether this will be achieved without large adverse effects on employment and wages is how quickly displaced workers are reemployed in other jobs.

Both analyses reach broadly similar conclusions: although some workers will be displaced by automation, other occupations will grow. While in the long-term the economy can adjust to provide enough work for everyone, automation will prove challenging for tens of millions of workers globally who will need to switch occupations. Depending on how societies manage this transition, unemployment could rise in the medium-term and wages could be eroded. Both the impact of automation and potential new sources of labor demand will play out differently from country to country.

250M
number of new jobs net of automation that could be created to 2030 by rising incomes

SEVEN GLOBAL TRENDS THAT WILL HELP SHAPE THE FUTURE OF WORK

In seeking to identify potential sources of labor demand to 2030, we started with a long list of trends and then prioritized seven for deeper analysis, based on high-level initial estimates of their potential for job creation (see Box 3, “Our analysis of seven trends that will contribute to future labor demand”). While there are many scenarios and sources of potential labor demand we have not included, the seven trends we focus on in this report have the potential to create demand for hundreds of millions of workers globally in the years to 2030, albeit with significant variations among countries.

For each trend, we model both the direct impact on employment and the indirect impact. By direct jobs, we mean employment created in a sector itself (for instance, increased spending on cars would create direct employment in the automobile manufacturing sector). Indirect refers to employment created in all the sectors that supply goods and services to the direct sector (for automobiles, indirect sectors would include spare parts, paint, leather, etc.). We do not include induced effects, since some are captured directly by our rising consumption trend.

Box 3. Our analysis of seven trends that will contribute to future labor demand

We examine potential labor demand created between 2016 and 2030 as a result of our seven trends, and compare that to the amount of work that could be displaced by automation. Sizing methodology varies by trend; however we capture direct and indirect jobs that could be created from each of our seven catalysts, take into account the decline in hours worked per person, and factor in globalization of work.[1]

For each occupation and sector, our incremental labor demand nets out automation and other productivity gains. We then compare that incremental labor demand with the reduction in labor demand due to automation against a projected 2030 baseline of employment. This uses the model we developed for our January 2017 report on automation, which also modeled ranges for the pace of technology development, and for automation adoption.[2]

As well as calculating direct and indirect labor demand from our select trends, we identified key occupations that will increase, and compare those with the occupations in which work could decline as a result of automation.

For three of the seven—investment in infrastructure, investment in buildings, and investment in renewable energy and energy efficiency—we examined two scenarios: a "trendline" scenario in which spending follows the observed trends across countries and a "step-up" scenario, in which labor demand increases as a result of societal and policy choices. For a fourth trend, the increasing shift to market of services that were long done without remuneration, we only examine a step-up scenario that assumes rising female participation in the workforce.

Our analysis offers a static view of the potential labor demand that could be created from the seven trends and does not factor in supply-demand dynamics and feedback from factors such as changes in wage levels. (For a more dynamic view, we used the McKinsey Global Growth Model, as we discuss later in this chapter). The labor demand that our seven trends could generate is potential, and whether this potential is captured will depend on the choices and investments made by businesses, policy-makers, and workers. The scenarios we construct do not take into account any sources of labor demand outside of our seven trends. We do not model entirely new industries, occupations, and activities that could be invented in the future, in part enabled by technology; one study suggests that on average, 0.5 percent of the workforce has been working in "new jobs" per year.[3] We do not take into account sectoral shifts in industries that are not directly related to automation or these seven trends, such as the rise of e-commerce in retail. We also do not model changes in work structure, such as the growth of the gig economy, or activities within an occupation that could change as a result of technological innovation. A more detailed discussion of our methodology can be found in the technical appendix.

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1 Our estimates of potential labor demand from each driver exclude growth in employment from population growth until 2030.

2 Ibid. *A future that works*, McKinsey Global Institute, January 2017. See also, *Shaping the future of work in Europe's digital front runners*, McKinsey & Company, October 2017.

3 Ibid. Jeffrey Lin, "Technological adaptation," May 2011.

Rising incomes in emerging economies will create large-scale new labor demand as spending increases on consumer goods, health care, and education

Rising GDP per capita generates higher spending on consumer goods and services, health care, and education, especially in emerging economies, and is the largest driver of labor demand we have identified (Exhibit 14). Prior MGI research has found that rising per capita consumption will generate about three-quarters of global consumption growth in the period from 2015 to 2030, with population growth accounting for the remaining 25 percent.[71] The expanding consuming classes in emerging economies will drive most of this increase. As incomes rise, consumers will spend disproportionally more on discretionary goods and services such as automobiles, leisure, and accommodation and food services, but they will also increase their non-discretionary spending on essentials such as food and clothing.[72] We estimate that this higher consumer expenditure could create between about 250 million and 280 million new full-time equivalent jobs, net of automation, across the 46 countries in our model. The growth due to rising incomes can mitigate automation's expected toll on workers in retail and accommodation and food services; retail salespeople, food preparation workers, and waiters see some of the largest boosts from higher consumer spending.

While this spending will create labor demand locally in sectors such as manufacturing, retail, accommodation and food services, as well as personal services, it will also create labor demand in other countries that export goods and services to these countries. We assume that a proportion of demand for tradable goods such as apparel and furnishing will continue to be served by countries rich in natural resources or with strong manufacturing or service sectors. For the purposes of simplifying our modeling, we assume current shares of global exports to remain constant; our model assumes that a country such as Germany will continue to serve its 2014 share of 18.5 percent of all automotive exports in 2030.[73]

Higher GDP per capita is also generally correlated with higher expenditures in health care and education. Access to health care, defined as the number of care providers (such as physicians) per capita, could increase, especially in fast-growing emerging economies such as India that currently have poor access to health care. We estimate that greater access to health-care providers alone at all levels, including physicians and medical assistants, could increase labor demand by 26 million to 43 million jobs (64 percent direct jobs in health-care provision and 36 percent indirect jobs in other sectors).[74] Demand for health-care providers could increase the most in developing countries such as India and China with the highest economic growth, although this may be contingent on the necessary provision of funding for health care by governments and consumers.

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71 *Urban world: The global consumers to watch*, McKinsey Global Institute, April 2016.

72 We model scenarios around the potential developments of shares of expenditure on different product categories in line with observable cross-country trend lines. See the technical appendix.

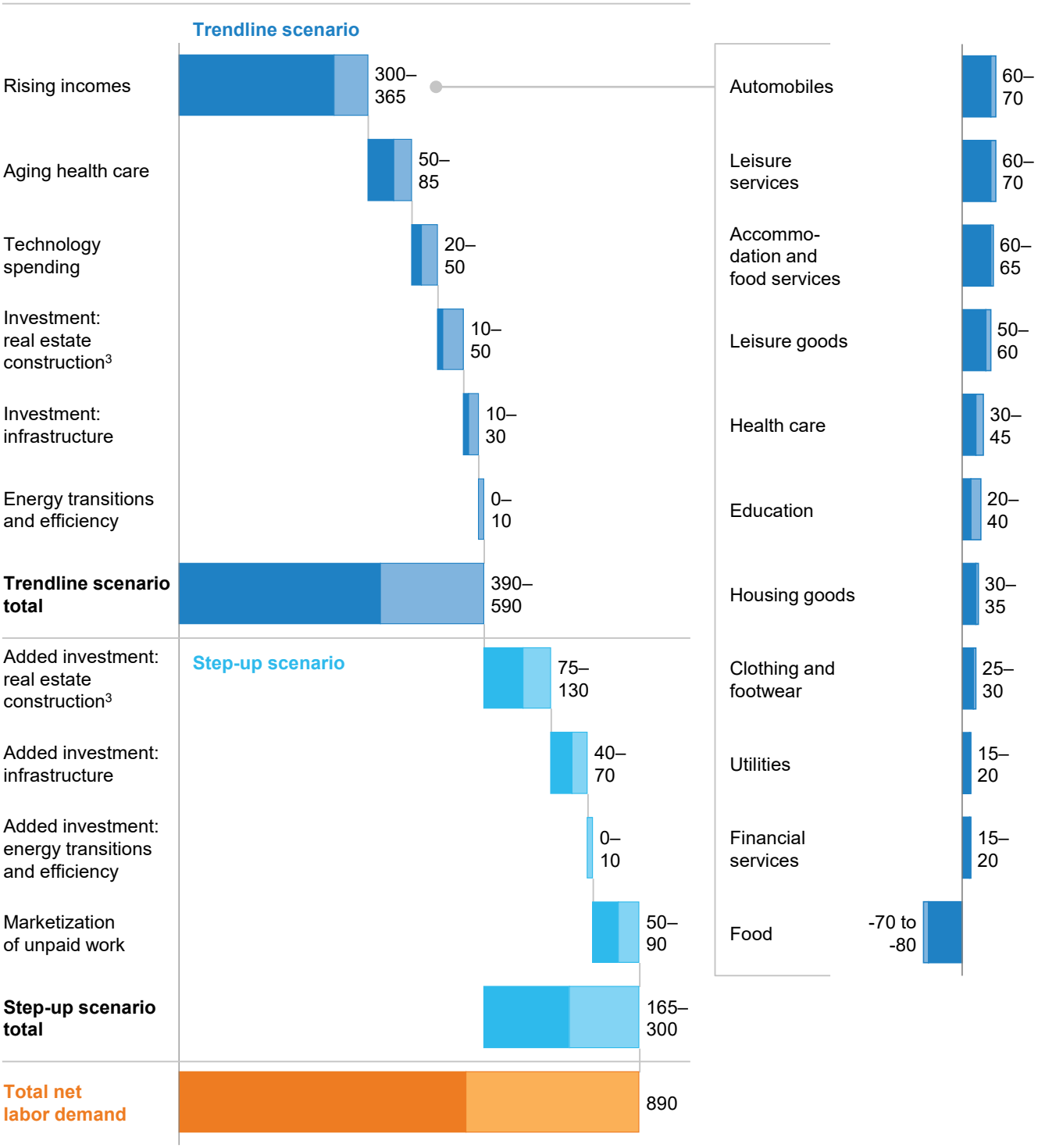
73 World Trade Organization, June 2017.

74 Similar to consumer expenditure, the numbers are modeled around observable trends between health-care employment and economic growth. It is important to note that the creation of these jobs will depend on funding from governments.

Exhibit 14

Rising consumer incomes are the largest source of job creation among our seven catalysts

Potential jobs created from seven catalysts of labor demand, 2016–30[1]
Million FTEs, ranged low–high[2]



1 Includes 46 countries; see technical appendix for full list. Assumes the midpoint adoption of automation scenario. Some occupational data projected into 2016 baseline from latest available 2014 data.
2 Low–high range reflects variance of underlying trends beneath modeled labor demand; additional details in technical appendix
3 Does not include land.

SOURCE: McKinsey Global Institute analysis

In education, as with health care, economic development typically raises expenditures, with a rise in gross enrollment rates, particularly at secondary and tertiary levels, and falling student-teacher ratios as quality improves. Our analysis suggests that these continuing improvements could create demand for up to 37 million jobs (78 percent direct jobs in the education sector and 22 percent indirect jobs in other sectors) globally by 2030, especially in fast-growing emerging economies. We compared gross enrollment rates and student-teacher ratios of students in primary education and conducted regression analyses against GDP per capita. Using demographic projections to estimate the number of students by country in 2030, we use our projections for gross enrollment rate and student-teacher ratio to infer the potential labor demand for teachers and support staff across each educational level.

Education as a creator of labor demand is most important for countries such as India, which has low enrollment rates, particularly at secondary and tertiary levels, high student-teacher ratios, and high GDP per capita growth. In other countries including China, where demographic trends are likely to have a smaller impact on labor demand in primary and tertiary education, increases in gross enrollment rates for secondary education and decreasing student-to-teacher ratios could imply an overall positive impact on labor demand in education on an aggregate level. In advanced economies with aging populations, such as Germany and Japan, there will be limited increase in labor demand from education as the relative share of students in the overall population declines. However, as with health care, the creation of these jobs would depend on the allocation of sufficient funding from public, private, and philanthropic sectors.

The global trend of aging populations will create new and additional labor demand for health care

The global population is continuing to rise and will likely reach 8.5 billion people by 2030.[75] At the same time, the population in many countries, both developed and developing, is aging: by 2030, there will be at least 300 million more people aged 65 and above than there were in 2014.[76] The aging trend is particularly acute in countries such as China, Germany, Italy, and Japan; by 2030, about 25 percent of their population will be over 65, if current fertility rates and immigration trends continue. This aging trend is less significant in developing countries with younger populations such as India and Nigeria, which are experiencing a demographic dividend, but it is also not restricted to advanced countries and China. Brazil, for example, also has an aging population.[77]

As people age, their needs and spending patterns change—in particular, spending on health care. For example, spending on hospital care for an 85-year-old American is more than five times higher than for those 19 to 44 years old.[78] We estimate that shifts in demographics could create incremental demand for 51 million to 83 million workers globally (55 percent direct and 45 percent indirect), especially for health care occupations that focus on taking care of the elderly, such as home health aides, personal care aides, nursing assistants, and so on.[79] (As with all the estimates of incremental labor demand in this chapter, this figure is net of automation, which will displace work including in health care, according to our model). In countries with aging populations such as Japan or China, our model suggests that aging and related health-care needs could drive the creation of between 10 and 15 percent of net new labor demand.

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75 *Population by age and sex*, United Nations, June 2017.

76 For details of the aging trend and its effect on the global economy, see *Global growth: Can productivity save the day in an aging world?* McKinsey Global Institute, January 2015.

77 Population estimates and projections, World Bank, April 2017. For a discussion of the limitations of this view and further information, see the technical appendix.

78 US Center for Medicare and Medicaid Services.

79 Our estimates include primary health-care occupations, as well as directly and indirectly created labor demand, e.g., in health-care device manufacturing.

6M
new tech jobs could be created in India under our scenarios

Technology development and deployment will create additional employment

As technology development continues apace, the technology sector is expected to keep growing rapidly, and this in turn will create incremental labor demand to develop and deploy technology. The scale of this employment will be modest, however. Today, an estimated 2.9 million people are employed in the US high tech sector, but this is only 1.9 percent of the workforce. In Germany, about 2.4 percent of the workforce is in a high-tech occupation.

Higher consumer spending on technology products and services, which typically rises as incomes increase, and larger outlays by businesses that adopt technology to improve productivity and improve output as they grow, are driving the increased spending on software, hardware, and services. We modeled consumer and enterprise technology spending per capita with rising GDP per capita across countries in 2014. Assuming that the correlation holds, we estimate that by 2030 technology spend could increase by $1.7 trillion to $2 trillion of which about 70 percent would be on information technology (IT) services. This includes hardware/software support, outsourcing, IT consulting, implementation, and internal IT services.[80] This increased spending on technology will create demand for 20 million to 46 million incremental workers (55 percent direct and 45 percent indirect) globally, net of automation. They will be a mix of high-skill workers such as software engineers and electrical engineers as well as medium-skill workers including web developers and electronic technicians. While IT services jobs such as computer support specialists will remain largely local, demand for technology hardware and especially software will likely be served by the global players, for example China, Germany, India, the Netherlands, and the United States. More than half of all global tech jobs could be created in these five countries. Of these, the largest demand will likely land in China and India, with up to 13 million and six million jobs respectively. Both large economies are expected to go through significant digitization in the next decade and beyond.

Investment in infrastructure and buildings can create new labor demand, particularly in our step-up scenario

Infrastructure and buildings are two areas of historic underspending that may create significant additional labor demand if action is taken to bridge infrastructure gaps and overcome housing shortages. We modeled two scenarios: one in which annual investment follows the observed trends across countries and one in which significant additional investment is made to fill gaps in infrastructure and real estate.

Global infrastructure systems have not kept up with demand and housing shortages persist in many countries. In critical areas of infrastructure such as transportation, water treatment, and power grids, years of neglect are catching up with countries around the world. MGI has found that, from 2016 to 2030, the world needs to invest about 3.8 percent of GDP in economic infrastructure, or an average of $3.3 trillion per year, just to support expected rates of growth, with emerging economies accounting for some 60 percent of that.[81] In real estate, as many as 330 million urban households in emerging and advanced economies live in substandard housing or are financially stretched by housing costs.[82]

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[80] IT services includes work outsourced to companies such as Accenture and Infosys, but does not include consumer services such as Google or Facebook.

[81] *Bridging global infrastructure gaps*, McKinsey Global Institute, June 2016.

[82] For an overview of the global housing shortage, see *A blueprint for addressing the global affordable housing challenge*, McKinsey Global Institute, October 2014.

Under our trendline scenario, in which investment in infrastructure and buildings continues to follow patterns we have observed across countries, we note that spending on both of these increases as countries develop economically. Thus, if countries were to increase their spending on the current trajectory as they develop, our model shows that up to 53 million gross new jobs could be created by continued spending on buildings, and up to 34 million on infrastructure. Yet considerably more could be done than matching the investment levels of other countries. Any additional efforts would consequently stimulate increased labor demand, especially for middle-wage jobs that will otherwise be particularly affected by automation in some advanced economies.

In our step-up scenario, we assume that the infrastructure gap has been closed, and that infrastructure and building spending in 2030 is subsequently higher to sustain this higher level of infrastructure stock and investment. We used infrastructure stock averages across countries and real estate stock averages in the United States as a proportion of GDP to estimate the infrastructure and housing investment needed in 2030 to keep pace with projected economic growth.

This increased spending could create demand for an incremental 76 million to 134 million workers from added investments in building structures and 38 million to 72 million incremental workers from added investments in infrastructure. As with health care and education, the creation of those jobs will depend on the allocation of necessary investments by the private and public sector. About 30 to 40 percent of this labor demand could come from India, which has currently under-invested in infrastructure, is going through a process of large-scale urbanization, and would need to invest a significant amount to keep pace with an ambitious target of 6.5 percent annual growth in GDP until 2030. The currently unproductive nature of the construction sector in some emerging economies such as Nigeria and Indonesia, coupled with low wage rates that may slow the adoption of automation technologies, contribute to the labor-intensity of this sector. China has already made significant investments in infrastructure over the past decade and our model shows that it may not need as much incremental investment in 2030. Developed economies including the United States and Germany could also invest in building new and repairing or re-building existing infrastructure, creating additional employment opportunities in the construction sector, particularly for middle-wage jobs.

Investment in renewable energy and energy efficiency

We similarly modeled two scenarios of labor demand for investment in new energy sources and improving energy efficiency, depending on whether spending follows current trends or is accelerated. The energy landscape is shifting rapidly as the cost of renewable energies, such as wind and solar, falls sharply. A range of new technologies, from smart electricity meters to Internet of Things sensors in oil rigs and advanced leaching techniques in mines, is transforming both the production and the consumption of resources.[83] The global policy environment for energy has been shifting: with the conclusion of the Paris Agreement in December 2016, countries around the world pledged to take measures that would keep the global temperature rise this century below two degrees Celsius above pre-industrial levels.[84] The International Energy Agency estimated in 2015 that to reach this goal could take up to $16.5 trillion of investment by 2030, including increasing the share of renewables and by making buildings, transportation, and technologies more energy efficient.

[83] Ibid. *Beyond the supercycle*, McKinsey Global Institute, February 2017.

[84] While the United States has announced it will withdraw from the Paris Agreement, many other signatory countries and even local governments in the United States have said they will continue to support it and meet the emission reduction targets that it established.

Governments including those in India and China are already spending more heavily on renewable energy and climate adaptation measures. India, for instance, has announced its intention to increase its share of renewable power to as much as 40 percent by 2030.[85] Overall, our modeling indicates that moving to renewable energy and raising energy efficiency at current trends could contribute up to seven million new jobs globally in 2030, under our trendline scenario, and an additional four million to seven million under our step-up scenario. (These jobs are incremental to the increase in employment in the power sector driven by GDP per capita growth, which is modeled in our rising incomes driver discussed above.)

In the transition to new energy sources, we model the potential job creation as countries shift their capacity mix for electricity generation. Making these transitions will require significant investments in manufacturing, construction, and operations and maintenance of solar panels, wind turbines, and other equipment. Shifts in capacity mix create jobs in two ways. First, large amounts of fixed investment are needed to increase the capacity for the growing new energy source, creating jobs in manufacturing, construction, and installation. Second, jobs may also be created in the decreasing energy sources through decommissioning of fossil fuel and other generation facilities, as some countries decide to shut down nuclear plants. Jobs associated with the ongoing operations and maintenance of electricity generation are largely variable with capacity, so job levels here will depend on relative labor intensity of operations and maintenance between energy types. Renewable manufacturing is enjoying a remarkable period of productivity growth—across three leading renewables manufacturers, employees declined by 65 percent on average per gigawatt shipped in 2010 to 2014. If these productivity gains continue at an aggressive rate, renewables manufacturing is likely to be a comparatively less labor-intensive part of the renewables value-chain.

To attain the international goal of avoiding a rise of more than two degrees Celsius, the UN's Intergovernmental Panel on Climate Change has calculated that CO_2 concentrations in the earth's atmosphere need to be stabilized at 450 parts per million. That will require targeted policy choices, including accelerated transitions to renewables and increased spending on energy efficiency measures, both in industry and in housing. This in turn could have a significant impact on job creation. In our step-up scenario, using data from McKinsey & Company's Energy Insights, we modeled a more ambitious shift into renewables and higher investment in energy efficiency, which would create an additional four million to seven million jobs globally.[86] High productivity and further automation potential in energy reduce the opportunity for energy to have a transformative impact on the jobs story in many countries; in the United States, less than 1 percent of all full-time equivalents in 2014 were in utilities and mining. But major investments in renewable energy will be crucial to meeting global climate change goals, which could create middle-wage jobs along the way.

"Marketization" of unpaid work could create new jobs

Today, much work done in households—from childcare to cooking and cleaning—is unpaid and disproportionately performed by women. At least some of this work could be shifted to paid employment through daycare or pre-kindergarten schooling programs and senior care programs. Rising female labor participation rates could be one way to prompt this shift, which economists call "marketization"; social decisions to expand government-supported programs could be another (and those programs in turn might enable higher female labor force participation). In recent years, we have seen the rise of digital "sharing economy" platforms that enable consumers to purchase many household and personal services more conveniently and cheaply, including meals ordered online and delivered by hand, thereby

[85] *Remap: Renewable energy prospects for India*, International Renewable Energy Agency, May 2017.

[86] This modeling does not include an estimate of other issues related to climate change that could cause potential for incremental labor demand, such as reconstruction and carbon capture and storage.

increasing demand. Academic research has found that such platforms result in an increase in employment in the industry, both for traditional workers providing those services and for the newly self-employed workers on the platform.[87] The marketization of previously unpaid housework is already prevalent in some advanced economies, especially in urban areas. For example, more than 90 percent of three-year-olds are enrolled in preschools in France and Sweden, most of which are funded by the government. In comparison, the rate is about 70 percent in the United States and less than 15 percent in India.[88]

Women account for half of the global working-age population but generate only **37%** of GDP

Shifting unpaid housework and childcare to paid employment could boost the number of women in the workforce globally, if governments decided to invest in these areas (such as by providing universal preschool and paid family leave). Women currently account for half of the world's working-age population but generate only 37 percent of global GDP, and in some regions of the world—including India, other parts of South Asia, the Middle East and North Africa—their contribution to regional output is considerably lower still. At the same time, about 75 percent of the world's total unpaid care is undertaken by women, including the vital tasks that keep households functioning, such as childcare, caring for the elderly, cooking, and cleaning. This unpaid work amounts to as much as $10 trillion of output per year, roughly equivalent to 13 percent of global GDP.[89] In our analysis, we observe the average amount of unpaid time currently spent on childcare, adult care, cooking, and cleaning using time use surveys. As these unpaid activity hours move to the marketplace, we expect labor demand to increase for them. While productivity gains will reduce the net number of hours worked, we estimate that between 51 million and 89 million incremental jobs globally could be created from this step-up scenario of shifting currently unpaid domestic work to paid employment.

JOBS OF THE FUTURE: IMPACT OF NEW LABOR DEMAND VS. AUTOMATION

The seven trends we selected for our analysis provide us with indications about types of occupations that will be in demand to 2030, even net of automation of activities within those occupations. At the same time, our automation modeling highlights occupations that could decline, if the current activities within those occupations that are automated are not replaced by other activities. The patterns differ among countries. One of the key differentiating factors is wage rates, since our model assumes that automation adoption will generally be more rapid in countries such as Germany and Japan, with relatively higher wages, than in India, China, or Mexico, where wages are lower. But there are also differences among emerging economies depending on whether populations are aging and the occupation mix across sectors, among other factors.

Exhibit 15 shows the top five occupations that will grow in the United States based on each of the seven trends described above before accounting for displacement due to automation. These are primarily direct additions, for example registered nurses related to aging, or construction laborers and carpenters from the building out of infrastructure. But the list also includes indirect additions, such as accountants, customer service representatives, and lawyers, who will see greater demand as support functions within the health-care industry feel a boost from increased spending due to aging.

[87] Thor Berger, Chinchih Chen, and Carl Benedikt Frey, *Drivers of disruption? Estimating the Uber effect*, University of Oxford, Oxford Martin School, working paper, January 23, 2017.

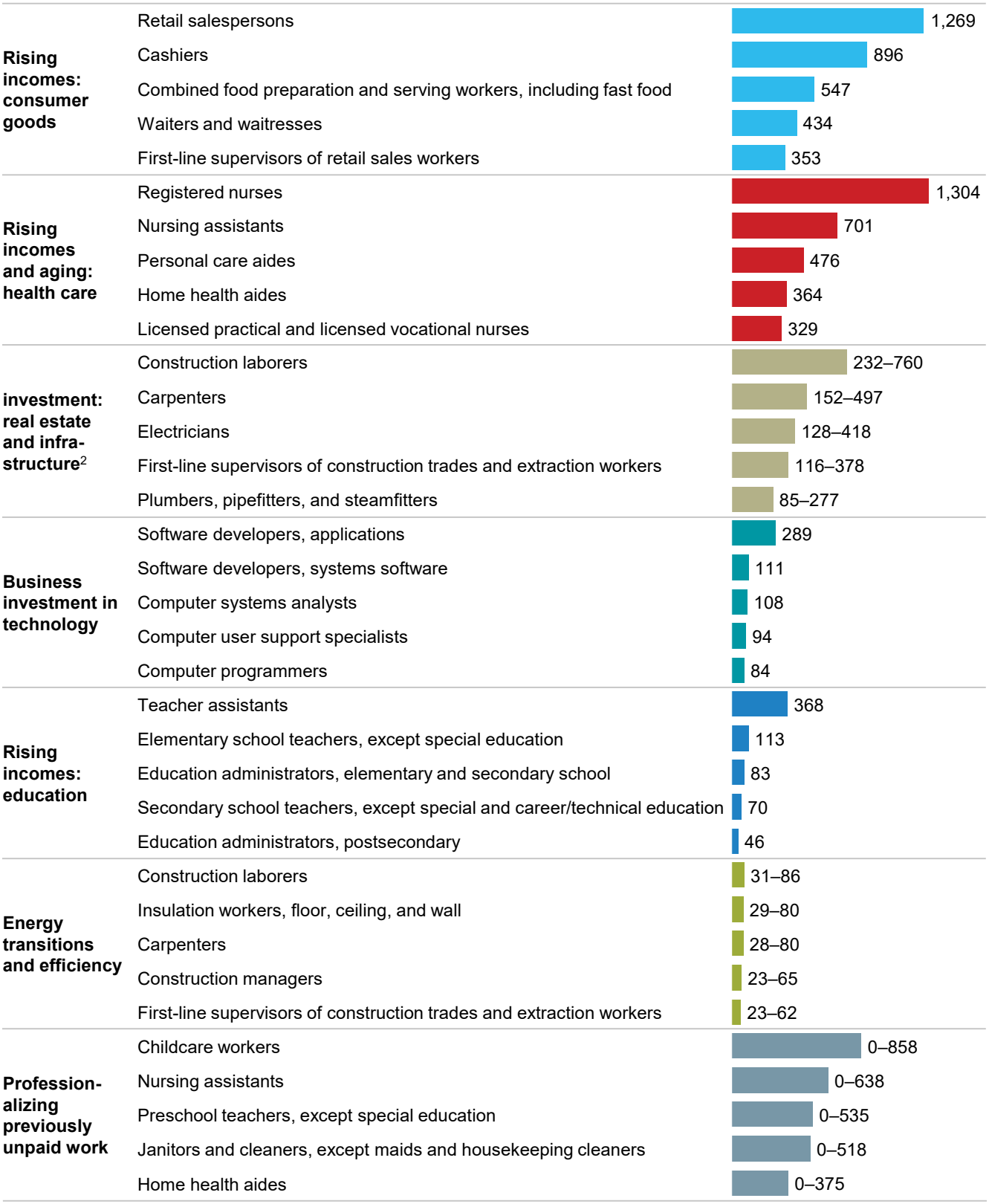
[88] OECD, 2014; *World development indicators*, World Bank, 2014.

[89] Ibid. *The power of parity*, McKinsey Global Institute, September 2015.

Exhibit 15

Each of our labor demand catalysts creates different types of jobs

US top five growing occupations by catalyst, trendline to step-up scenario, 2016–30[1]
Thousand


Rising incomes: consumer goods
Retail salespersons 1,269
Cashiers 896
Combined food preparation and serving workers, including fast food 547
Waiters and waitresses 434
First-line supervisors of retail sales workers 353
Rising incomes and aging: health care
Registered nurses 1,304
Nursing assistants 701
Personal care aides 476
Home health aides 364
Licensed practical and licensed vocational nurses 329
investment: real estate and infra-structure[2]
Construction laborers 232–760
Carpenters 152–497
Electricians 128–418
First-line supervisors of construction trades and extraction workers 116–378
Plumbers, pipefitters, and steamfitters 85–277
Business investment in technology
Software developers, applications 289
Software developers, systems software 111
Computer systems analysts 108
Computer user support specialists 94
Computer programmers 84
Rising incomes: education
Teacher assistants 368
Elementary school teachers, except special education 113
Education administrators, elementary and secondary school 83
Secondary school teachers, except special and career/technical education 70
Education administrators, postsecondary 46
Energy transitions and efficiency
Construction laborers 31–86
Insulation workers, floor, ceiling, and wall 29–80
Carpenters 28–80
Construction managers 23–65
First-line supervisors of construction trades and extraction workers 23–62
Profession-alizing previously unpaid work
Childcare workers 0–858
Nursing assistants 0–638
Preschool teachers, except special education 0–535
Janitors and cleaners, except maids and housekeeping cleaners 0–518
Home health aides 0–375

1 Some occupational data projected into 2016 baseline from latest available 2014 data.
2 Does not include land.

SOURCE: McKinsey Global Institute analysis

Advanced economies have a similar pattern of job growth and declines

In advanced economies, we identify six broad groups of occupations that will experience growth in labor demand from our trends, although the size of the increase will depend on country and on scenario. For example, in our step-up scenario, the demand for builders and construction workers rises considerably (Exhibit 16). Workers in occupations in the following groups spend considerable time on work activities that are among the least susceptible to automation based on our analysis, as they require human capabilities including social and emotional interaction, higher-level logical reasoning, creativity, and application of expertise that machines for now are less capable of accomplishing. The occupational groups that generally grow as a result of our drivers, even net of automation, are:

- **Care providers**: that is, doctors, nurses, home health aides and others in caring occupations who will be in greater demand as a result of rising health-care spending, both from increased prosperity and from aging. Given the disproportionate cost of health care for the elderly, aging is expected to be the predominant driver of increased health-care employment. Countries with aging populations such as Japan and China will see a sharp increase in occupations that work closely with seniors, for example nurses, nursing assistants, personal care aides, and home health aides.

- **Professionals**, defined as white-collar occupations that require academic training and expertise in a specific industry or functional area. These include accountants, engineers, and scientists. Most of these occupations cut across a wide range of sectors. While generally less automatable than other job types, certain supporting occupations such as paralegals and scientific technicians may face high automation.

- **Technology professionals.** Technology experts will be in continued demand everywhere as automation is increasingly adopted, although the total numbers remain quite small compared with other occupations. Occupations will include IT workers such as computer scientists and software developers, who typically have college educations, but also occupations such as web developers and electronics technicians, which only require a secondary education. That said, many of these latter occupations involve activities that are more automatable than technology workers with higher levels of education.

- **Builders.** In this category we have included architects, surveyors, and cartographers, as well as construction occupations and maintenance and repair workers, such as construction laborers, electricians, carpenters, and plumbers. Even though construction laborers primarily do physical work, their activities are mostly in unpredictable settings, and hence not as highly susceptible to automation by 2030.

- **Managers and executives** also cut across all sectors and cannot easily be replaced by machines, as much of their work involves interacting with and managing stakeholders. However some of their more routine activities will be automated, such as collecting information, analyzing data, or preparing reports.

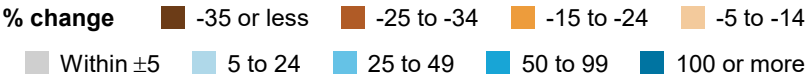
- **Educators.** School teachers and others will see a significant increase in demand, especially in emerging economies with young populations such as India. Childcare workers and early childhood educators will also grow under our step-up scenario in which more childcare is shifted to paid providers.

- **"Creatives"**: Rising incomes in emerging economies will create more demand for leisure and recreational activities. This in turn will create demand for artists, performers, and entertainers, although the total numbers will remain relatively small.

Exhibit 16

Jobs of the future: Employment growth and decline by occupation

Net impact of automation and seven catalysts of labor demand, 2016–30
% change (+/–), step-up labor demand, midpoint automation[1]



Occupation groups *% of labor force across 6 focus countries*	Occupational categories	United States	Ger-many	Japan	China	Mexico	India
Care providers *1–9*	Doctors						
	Nurses, physicians assistants, and pharmacists						
	Therapists						
	Health aides and health support						
	Childcare workers						
	Health technicians						
	Community and social workers						
Educators *1–5*	School teachers						
	Postsecondary teachers						
	Other education professionals						
	Education support workers						
Managers and executives *2–5*	Executives						
	Managers						
Professionals *2–19*	Account managers						
	Engineers						
	Business and financial specialists						
	Math specialists						
	Scientists and academics						
	Lawyers and judges						
	Legal support workers						
Technology professionals *0–2*	Computer engineers						
	Computer specialists						
Builders *5–11*	Building engineers						
	Architects, surveyors, and cartographers						
	Construction workers						
	Installation and repair workers (buildings & infrastructure)						
	Crane and tower operators						
Creatives *0–1*	Artists and designers						
	Entertainers/media workers						

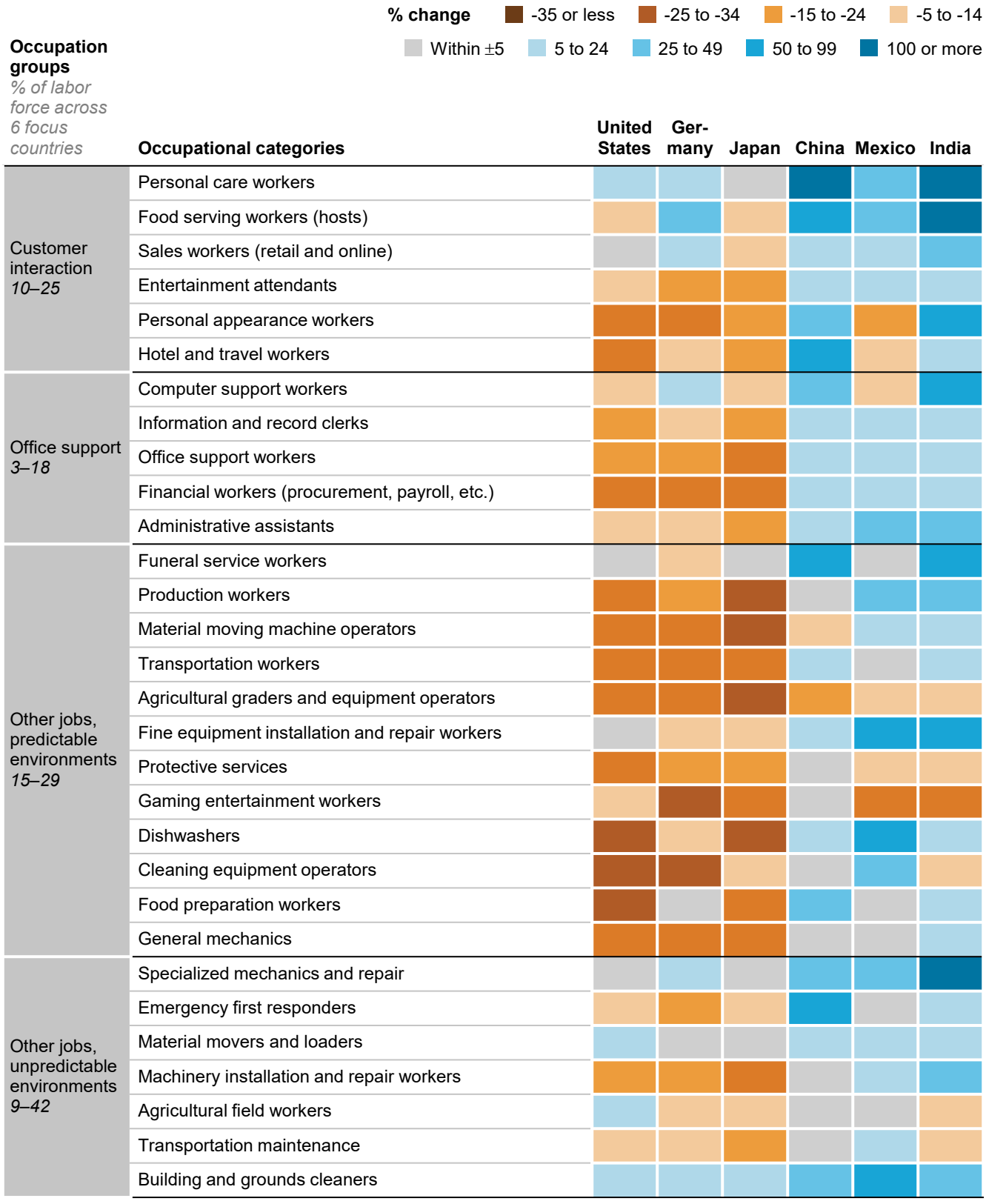
1 Midpoint of earliest and latest automation adoption in the "step-up" scenario (i.e., high job growth). Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: US Bureau of Labor Statistics; McKinsey Global Institute analysis

Exhibit 16

Jobs of the future: Employment growth and decline by occupation (continued)

Net impact of automation and seven catalysts of labor demand, 2016–30
% change (+/–), step-up labor demand, midpoint automation[1]



Occupation groups *% of labor force across 6 focus countries*	Occupational categories	United States	Germany	Japan	China	Mexico	India
Customer interaction *10–25*	Personal care workers						
	Food serving workers (hosts)						
	Sales workers (retail and online)						
	Entertainment attendants						
	Personal appearance workers						
	Hotel and travel workers						
Office support *3–18*	Computer support workers						
	Information and record clerks						
	Office support workers						
	Financial workers (procurement, payroll, etc.)						
	Administrative assistants						
Other jobs, predictable environments *15–29*	Funeral service workers						
	Production workers						
	Material moving machine operators						
	Transportation workers						
	Agricultural graders and equipment operators						
	Fine equipment installation and repair workers						
	Protective services						
	Gaming entertainment workers						
	Dishwashers						
	Cleaning equipment operators						
	Food preparation workers						
	General mechanics						
Other jobs, unpredictable environments *9–42*	Specialized mechanics and repair						
	Emergency first responders						
	Material movers and loaders						
	Machinery installation and repair workers						
	Agricultural field workers						
	Transportation maintenance						
	Building and grounds cleaners						

1 Midpoint of earliest and latest automation adoption in the "step-up" scenario (i.e., high job growth). Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: US Bureau of Labor Statistics; McKinsey Global Institute analysis

By contrast, our analysis suggests that, in advanced economies, other occupations will see a net decline by 2030, with more work automated than created by our seven trends, assuming they do not add non-automated activities. These include:

- **Some customer interaction jobs**, including hotel workers, travel agents, entertainment attendants, and cafeteria workers.
- **Office support jobs**, including information clerks, payroll processors, and administrative assistants.
- **Jobs carried out in predictable settings.** These are among the most susceptible to automation and include factory workers, material moving machine operators, transportation workers, and installation and repair workers.

It is important to note that even occupations that may have a net decline due to automation will not disappear: rather, their numbers could shrink from today's levels in the next 15 years. For instance, even though some of the current activities of food preparation and serving workers could be automated (for example, by ordering kiosks in fast food restaurants), and about one-fifth of their hours worked could be automated under our midpoint adoption scenario, there could still be demand in the United States for more than three million of them.

Developing countries see net job growth in nearly all occupational groups

The picture is rather different in rapidly growing and low-income countries such as India, where we see net job growth in nearly every occupational category. This is for two reasons: low wages mean delayed adoption of automation, and relatively high GDP growth creates jobs across the economy, including in predictable environments that are among the most affected in advanced economies. For example, production workers would rise 34 percent in India under our step-up scenario, compared with a 28 percent decline in the United States and a 56 percent drop in Japan.

34%
potential increase in production workers in India under our step-up scenario

Middle-income countries such as China and Mexico also have net job growth in a range of occupations under our scenarios that in advanced economies experience declines. This is the case with the category of workers who are primarily engaged in customer interaction, such as entertainment attendants, and food-service workers. These types of occupations will remain in high demand in emerging economies including China, as a result of rising consumption from an increasingly prosperous consuming class. However, in Mexico, the potential growth is not as large as in India, reflecting the lower GDP growth and higher wages.

WILL THERE BE ENOUGH WORK IN THE FUTURE?

The public debate in many countries over automation can quickly focus on the existential question of whether there will be enough jobs for workers in a future marked by automation. We can see from history that such fears have so far been unfounded: over time, labor markets have adjusted to changes in demand for workers from technological disruptions, although in some eras real wages have remained depressed for some time. We address this question of whether there will be enough work in the future through two different but complementary sets of analyses. The first is based on our model of new and additional labor demand and automation described above, using the select trends we have identified, and provides only a partial view. For the other analysis, we used a macroeconomic model of the economy that incorporates the dynamic interactions among various factors.

Both analyses point in the direction that, in most scenarios, there can be enough new job creation to offset the impact of automation. But a larger challenge will be ensuring that workers have the skills and support needed to transition to new jobs. Countries that fail to enable and smooth these transitions could see rising unemployment and depressed wages.

Outcomes will vary significantly by country, depending on four factors

We find a significant difference of likely outcomes among countries, with four factors largely influencing the extent to which enough new jobs will be created to offset those displaced by automation. The four factors are:

- **Wage levels.** Advanced economies will likely adopt automation in the workplace earlier and faster than emerging economies since their wages are relatively higher, making the business case for automation stronger. (Our model assumes that automation begins to be adopted only when its cost reaches parity with the cost of human labor). Advanced economies will therefore likely see the largest impact from automation in the next 15 years.

- **Demand growth.** Economic growth is essential for job creation. While it may sound obvious, economies that are stagnant or growing only slowly create few, if any, net new jobs. Countries with the most rapid GDP growth rate per capita will have higher growth rates of consumption and spending, thus stimulating greater proportional increases in labor demand. Slower-growing economies will create jobs at a slower rate. Advanced economies have much lower projected rates of GDP growth than developing countries, reflecting aging workforces and also less rapid productivity growth. Developing countries such as India and China are projected to have much higher GDP per capita growth rates, which will contribute to job creation. Furthermore, innovation and entrepreneurship often underlie the creation of new business models and work activities, another catalyst of job growth.

- **Demographics.** The outcome of automation and future labor demand will play out very differently in countries with a young and rapidly-growing population, such as India, compared with countries that have a shrinking population and workforce, such as Japan. Countries with a growing workforce have a potential "demographic dividend" that will lift growth. However, rapid growth of the population will bring millions more young people into the workforce, creating considerable pressure to expand formal employment opportunities. While the impact of automation will be less, given lower wage rates in these countries, automation will make this already considerable challenge more difficult. In Germany and Japan, by comparison, aging is reducing the working-age population, which reduces the need for economic growth and the potential impact of automation.

- **Mix of economic sectors.** The automation potential of national economies differs among countries depending on the structure of their economies and, within the economy as a whole, on the mix of sectors, occupations, and their constituent work activities. Japan, for example, has a higher automation potential than the United States because the weight of certain sectors that are highly automatable, such as manufacturing, is higher in Japan; 17 percent of jobs in Japan are in the manufacturing sector compared with 9 percent in the United States. And within the manufacturing sector itself, Japan is more susceptible to automation because a larger proportion of the jobs involve tasks that can be more easily automated, such as production.

These factors combine to create different outlooks for the future of work in each country. In general, countries with similar characteristics across these four factors could see broadly similar outcomes from automation adoption, albeit with nuances for cultural and other differences. Some clusters are apparent. For example, developed countries with aging populations and high wages that will accelerate automation adoption—such as Germany, Italy, and Japan—could follow a similar trajectory, as will developed countries with younger populations, such as Canada, France, Sweden, the United Kingdom, and the United States. Across the Middle East, countries such as Kuwait, Saudi Arabia, and the United Arab Emirates share similarities on demographics and automation adoption and, to a lesser extent, on GDP per capita. Developing countries with the youngest populations, including Egypt, Kenya, and Nigeria, will face similar challenges to grow aggregate demand, given their fast-growing workforce.

Our scenarios of new and additional labor demand, net of automation, while incomplete, suggest ample job creation to 2030

We compare the number of jobs created by the seven selected trends identified above with the number of jobs expected to be displaced by automation. We are conscious that this exercise paints an incomplete picture. While our seven trends model the major sources of new labor demand, they do not account for induced job demand creation nor the creation of novel work activities and occupations. One research study has found that, each year, roughly 0.5 percent of the US labor force is employed in an occupation that did not exist in the prior year—in other words, performing an entirely new set or combination of work activities. By 2030, this would imply that 9 percent of the US labor force could be employed in occupations that do not exist today.[90] Just as many occupations today, such as search engine optimization, app designers, and website designers, would have been impossible to imagine in the pre-Internet era, we cannot foresee the new occupations that will arise in the future.

In order to address the question, "Will there be enough work in the future?," we compare the net effects of jobs displaced by automation, jobs created by the seven trends, the creation of new work and other unsized labor demand, and demographic changes in labor force size. Even limiting our estimates of new and additional job creation to the select factors that we model, we find that our focus countries could generate enough labor demand to offset the impact of automation and take into account changes in the size of labor forces.[91] Nevertheless, our modeling from the seven trends indicates that the transition toward 2030 looks quite different depending on the country (see Exhibit 17).

For instance, Japan is rich but projected to grow slowly to 2030. It faces the combination of slower job creation coming from economic expansion and a large share of work that can be automated as a result of high wages and the structure of its economy. However, Japan will also see its workforce shrink by 2030 by four million people. In the step-up scenario, and considering the jobs in new occupations we cannot envision today, Japan's net change in jobs could be roughly in balance.

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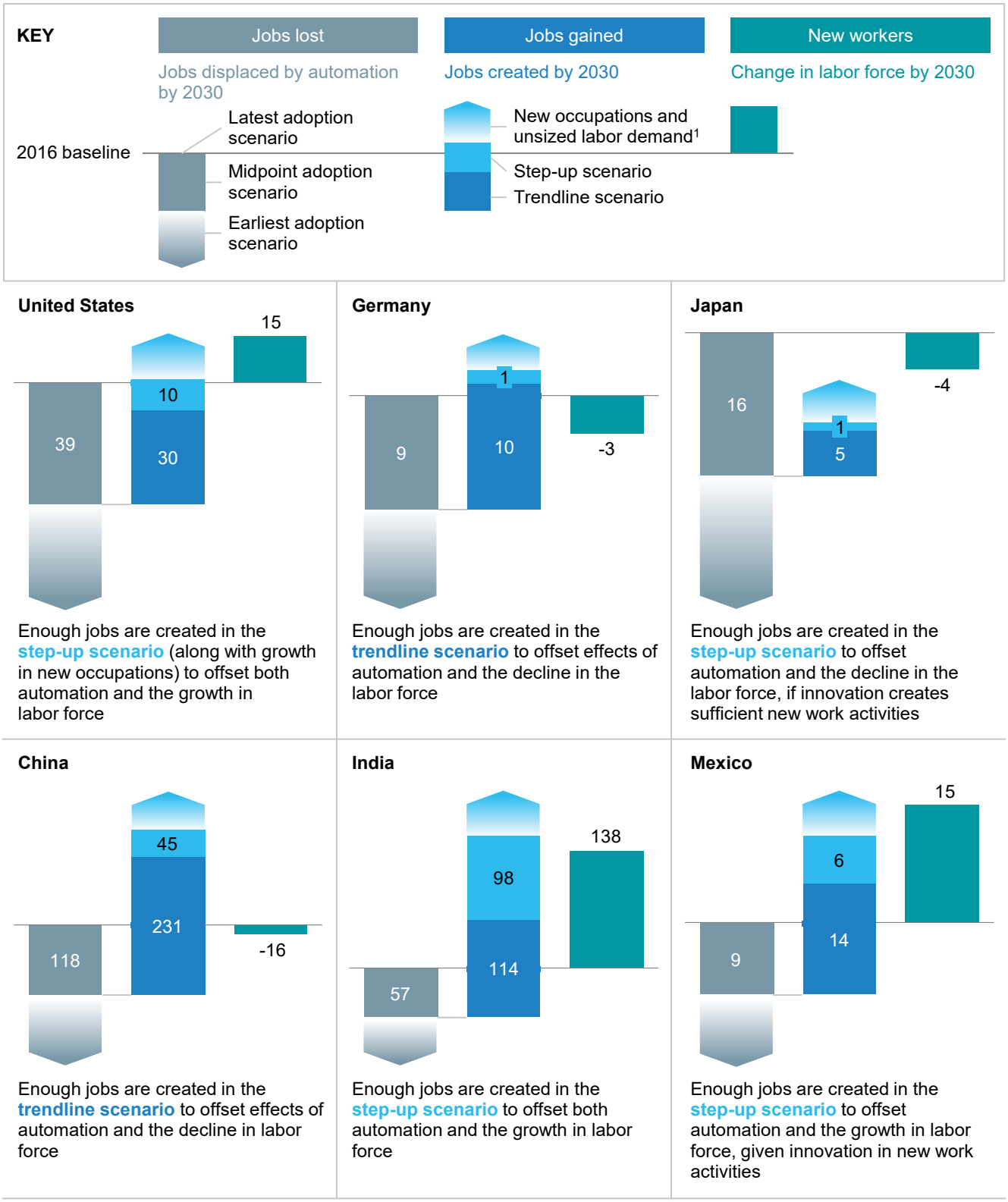
[90] Ibid. Jeffrey Lin, *Technological adaptation*, 2011.

[91] Our results are broadly in line with prior research by McKinsey & Company in nine northern European digital "front-runner" countries. This research suggests that technology diffusion contributed 0.4 to 0.6 percentage points, or around 30 percent, to GDP growth between 1990 and 2016 in the nine countries. Digital technology replaced jobs at a rate of about 120,000 jobs a year between 1999 and 2010, and boosted employment by around 200,000 jobs a year, creating positive net employment of 80,000 jobs per year. More than half of the new jobs were high-skill. *Shaping the future of work in Europe's digital front-runners*, McKinsey & Company, October 2017.

Exhibit 17

Jobs lost, jobs gained: Automation, new job creation, and change in labor supply, 2016–30

Range of automation scenarios and additional labor demand from seven catalysts


KEY
Jobs lost
Jobs displaced by automation by 2030
Jobs gained
Jobs created by 2030
New workers
Change in labor force by 2030
2016 baseline
Latest adoption scenario
Midpoint adoption scenario
Earliest adoption scenario
New occupations and unsized labor demand[1]
Step-up scenario
Trendline scenario
United States
39
10
30
15
Enough jobs are created in the step-up scenario (along with growth in new occupations) to offset both automation and the growth in labor force
Germany
9
1
10
-3
Enough jobs are created in the trendline scenario to offset effects of automation and the decline in the labor force
Japan
16
1
5
-4
Enough jobs are created in the step-up scenario to offset automation and the decline in the labor force, if innovation creates sufficient new work activities
China
118
45
231
-16
Enough jobs are created in the trendline scenario to offset effects of automation and the decline in labor force
India
57
98
114
138
Enough jobs are created in the step-up scenario to offset both automation and the growth in labor force
Mexico
9
6
14
15
Enough jobs are created in the step-up scenario to offset automation and the growth in labor force, given innovation in new work activities

1 Historical analysis suggests that we could expect 8–9% of 2030 labor supply will be in "new jobs," which is additional to labor demand we have estimated.
NOTE: We identified seven catalysts of labor demand globally: rising incomes, health-care spending, investment in technology, buildings, infrastructure, and energy, and the marketization of unpaid work. We compared the number of jobs to be replaced by automation with the number of jobs created by our seven catalysts as well as change in labor force, between 2016 and 2030. Some occupational data projected into 2016 baseline from latest available 2014 data. Not to scale.

SOURCE: McKinsey Global Institute analysis

Like Japan, the United States and Germany also face significant workforce displacement from automation by 2030, but their projected future growth—and hence new job creation—is higher. However, the United States has a growing workforce. In the step-up scenario, and considering new occupations that may arise, it is roughly in balance. Germany's workforce will decline by three million by 2030, and it will have more than enough labor demand to employ all workers.

At the other extreme is India: a fast-growing developing country with relatively modest potential for automation over the next 15 years, reflecting low wage rates. Our analysis finds that most occupational categories are projected to grow in India, reflecting its strong economic expansion. However, India's labor force is expected to grow by 138 million people by 2030, or about 30 percent. Employing these new entrants in formal sector jobs will require job creation on a much larger scale than in the past. Automation will make this challenge more difficult; some fear "jobless growth" will make the challenge greater. However, our analysis suggests that India can create enough new jobs to offset automation and employ new entrants, for example by undertaking the investments in our step-up scenario.

China and Mexico have higher wages than India, and so are likely to see more automation. China still enjoys robust economic growth and will have a shrinking workforce; like Germany, China's problem could be a shortage of workers. Given net job creation as well as declining labor forces, China and Germany may need to explore different options such as accelerating automation adoption or immigration in order to fulfill the expected creation of growing future labor demand. Mexico's rate of future economic expansion is more modest than China's, and its workforce will grow by 15 million by 2030. Like the United States and Japan, our results suggest that Mexico may need the extra job creation from the step-up scenario plus innovation in new occupations to make full use of its workforce.

Our macroeconomic modeling highlights the critical importance of rapid reemployment of workers displaced by automation

The analysis of net job creation given expected automation rates and the seven trends is an informative but incomplete exercise, even after adjusting for labor supply changes and the creation of new occupations. This is because the analysis above does not take into account dynamic interaction among the trends, such as the impact of automation investment and automation-related unemployment on GDP growth rates or economy-wide average wage rates. Thus, to develop a perspective on the potential net impact of automation and job creation potential of the economy, we use a general equilibrium model in order to triangulate our results with the analysis from the seven trends (see Box 4, "Modeling the economic impact of automation").

The overall result of the general equilibrium model is the same as the result from the seven trends: it shows that labor markets will generally be flexible enough to absorb the workers displaced by automation. Furthermore, like the outcome of the analysis from the seven trends, differences arise between countries in the expected transition toward 2030. The general equilibrium model points toward a strong distinction in the expected transition between the advanced economies and the emerging economies we focus on in this report.

Box 4. Modeling the economic impact of automation

We used McKinsey & Company's Global Growth Model to model the dynamic impacts of automation on the economies of our six focus countries.[1] This is a supply-side general equilibrium macroeconomic model that covers more than 100 countries with data from 1960 through 2015.

In the model, we directly included three factors by which automation affects economic growth: labor displacement, resulting in workers losing their jobs; capital investment needed to implement the automation technologies; and an increase in productivity growth, as firms employ more capital per worker. These inputs to the Global Growth Model are derived from our automation research. To calculate the impact on productivity, we estimate the implied productivity growth that would be needed to maintain constant total output with fewer workers, under the rationale that firms would not adopt the new technology unless it produced at least the same level of output. In reality, this is likely to be an underestimate of the impact. Our experience working with firms and our prior automation research shows that automation often results in higher quality output and significantly higher level of output as well.

We also model how quickly displaced workers are employed in new jobs, or the reemployment rate. Not every displaced worker will enter unemployment; some will have the skills and the opportunity to transition quickly into a new role at the same company or with a new firm. Indeed, each year millions of US workers leave a job and find a new one. Between 2013 and 2015, 66 percent of displaced workers in the United States found a new job by the end of the period; 49 percent of workers displaced between 2007 and 2009, during the financial crisis, were reemployed by the beginning of 2010.

We model four reemployment rate scenarios—low, medium, high, and full reemployment. The reemployment rates modeled differ by country and are estimated from literature and adjusted for labor market flexibility factors.

[1] The structure of the model is anchored in the academic literature on economic growth models. For details see *Shifting tides: Global economic scenarios for 2015–25*, McKinsey & Company, September 2015.

In advanced economies, all scenarios result in full employment by 2030, but the transition may include a period of higher unemployment and wage adjustments

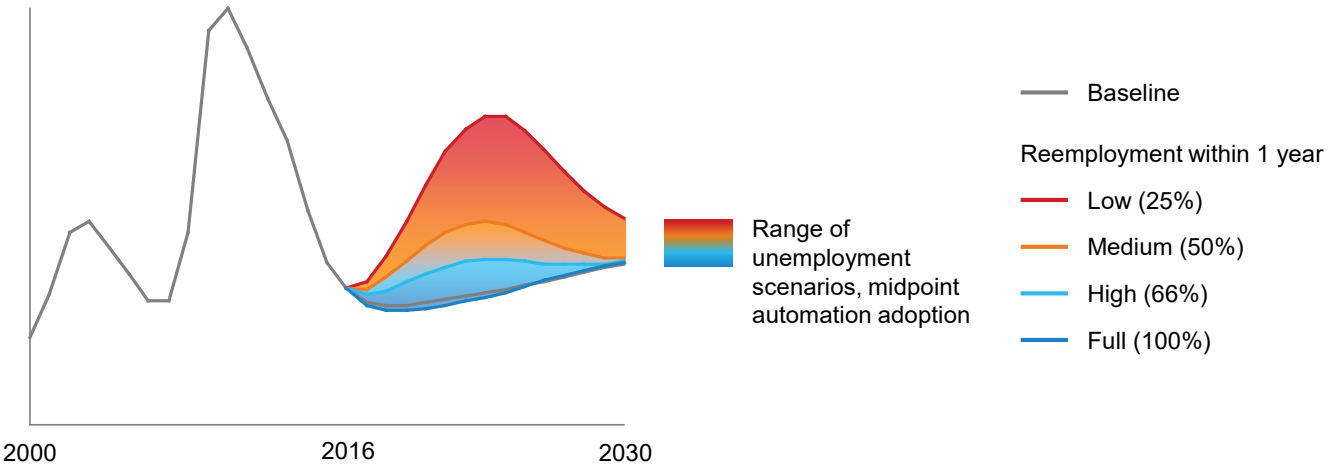
For the three advanced economies we focus on in this report—Germany, Japan, and the United States—economies are flexible enough to absorb most if not all the displaced workers by 2030 in all reemployment scenarios. The pace at which displaced workers are reemployed is critical: lower reemployment leads to higher medium-term unemployment, while in the highest reemployment scenario, the labor displaced by automation will be reemployed fast enough such that the unemployment rate does not rise (Exhibit 18).

Automation will also have a wage impact. Our modeling results in a temporary increase in wages in all reemployment scenarios because of increased productivity as a result of automation. But, as with the unemployment rate, wages will also depend on the pace of reemployment. In the lower reemployment scenarios, wages fall in the long-run in response to high medium-term unemployment. This leads to a lower labor share of income, as the gains of automation in this scenario primarily accrue to capital owners, not laborers. Conversely, in the highest reemployment scenario, wage growth is expected to persist, and thus the decades-long trend of declining labor share of income slows or even reverses by 2040.

Exhibit 18

Unless displaced workers are reemployed quickly, medium-term unemployment could rise

US unemployment rate



NOTE: These unemployment scenarios based on reemployment rates are hypothetical simulations derived from McKinsey & Company's Global Growth model.

SOURCE: McKinsey Global Institute analysis

In emerging economies, automation's impact on employment is smaller than in advanced economies

The impact of automation is lesser in China, India, and Mexico than in the advanced economies we focus on, according to our simulation. First, automation rates are expected to be lower, leading to smaller percentages of displaced workers, lower levels of capital investment, and smaller productivity increases. As such, unemployment is not expected to rise significantly, nor are modeled wages or GDP growth sensitive to the automation effect under any of the reemployment scenarios.

For more detailed analysis of each of our six focus countries, see the country impact section starting on page 91.

•••

Automation will displace jobs around the world by 2030, but in our analysis demand for certain types of labor—from care providers to builders—will also increase, spurred by the rising consumer class in emerging economies and the growing health-care needs of aging populations in nations from Germany and Italy to China and Japan, among other trends. Our dynamic modeling of the US and other economies suggests that enough new jobs will be created to return to full employment by 2030, but the transition could be difficult. Depending on the rate at which displaced workers are reemployed, the unemployment rate could rise in the short- to medium-term, and wages may fall thereafter. Moreover, our analysis highlights differences between the sorts of jobs that will be lost from automation, and those that will be gained from a range of trends. Even if there is enough work to go around in 2030, millions of individuals may need to find new jobs and possibly acquire new skills. We examine these trends in the next chapter.

Midcareer retraining will be a major challenge
© Hero Images/Getty Images

4. IMPLICATIONS FOR SKILLS AND WAGES

The combination of labor displacement by automation and changing demand for occupations that we have outlined in the previous chapters will have enormous implications for individual workers. We estimate that 60 million to 375 million individuals around the world may need to transition to new occupational categories by 2030 , in the event of midpoint or early automation adoption (although that number would be negligible in 2030 in our edge-case slow automation adoption scenario). Nearly all jobs will involve a shifting mix of tasks and activities.

Within occupations, the mix of activities and the capabilities required will skew toward more personal interactions and more advanced levels of cognitive capabilities. Educational requirements will also change: net of automation, a greater share of jobs in the future will likely require higher levels of educational attainment. In advanced economies, that includes increasing demand for jobs that currently require a college degree (or other advanced training). At the same time, employers and workers may need to take a more fine-grained approach to identify skills that are the most important.

Our results also suggest that income polarization in advanced economies including the United States could be exacerbated.[92] We do not dynamically model how wages might change for individual occupations by 2030, but based on current wages, we find that in most advanced countries, middle-wage jobs may decline the most as a result of automation. Growing occupations in these countries will tend to be either those that are less remunerative, for example, retail salespeople or childcare workers, or quite the opposite: highly paid jobs, such as software engineers. In developing economies including China, however, we see the opposite trend. Here the strongest job growth will likely be for middle-wage occupations, including service and construction jobs.

Up to
375M
workers globally may need to transition to new occupational categories by 2030

THE MIX OF ACTIVITIES WITHIN OCCUPATIONS WILL CHANGE

For nearly all occupations, automation will change the mix of activities that humans perform, as some tasks are taken over by machines or software. Over time, occupational definitions may change, as the boundaries between different occupations become blurred. Already, physician assistants and registered nurses carry out many tasks that doctors used to do, such as handling routine cases or giving shots. For their part, doctors now write up memos and enter data rather than dictating to assistants.

With automation, such shifts may become more pronounced, although the specifics will vary by country. In Germany, workers of the future will likely spend more time on activities that require applying expertise (+2.9 billion full-time equivalent hours), interacting with stakeholders (+1.5 billion hours), and managing people (+1.4 billion hours), and less time on predictable physical activities (-2.6 billion hours), collecting data (-2.5 billion hours) and processing data (-2.1 billion hours), where machines already exceed human performance (Exhibit 19). In other words, many of the rote activities that have dominated the workplace in the post-industrial age will be taken over by machines. Work activity will shift to human interaction and working in unpredictable environments—and will also require increasing application of expertise. Similar shifts will occur in other high-wage, advanced economies.

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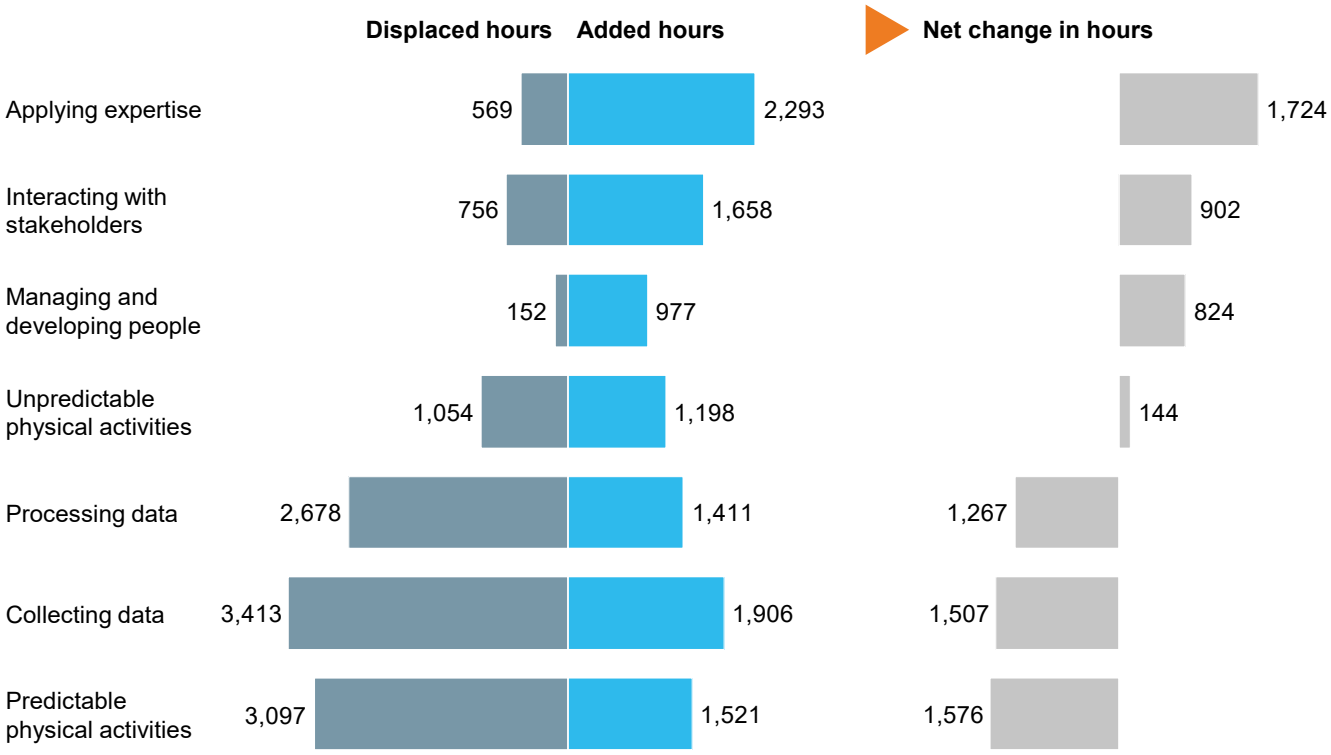
[92] See, for example, Daron Acemoglu and David H. Autor, "Skills, tasks, and technologies: Implications for employment and earnings," in *Handbook of Labor Economics*, Volume 4, Orley Ashenfelter and David E. Card, eds., 2011.

Exhibit 19

Activities within all occupations will shift: New work will involve more application of expertise, interaction, and management

Total hours by activity type, Germany example, 2016–30 (midpoint automation, step-up demand)
Million FTE hours



NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: US Bureau of Labor Statistics; McKinsey Global Institute analysis

In India, much of the projected growth in activity hours will be in physical activities, driven by demand for construction work, particularly in the step-up scenario. China, which has higher levels of existing infrastructure and building development, will still see some growth in physical activities. However, most of the growth will be in activities similar to its advanced-economy counterparts, such as interacting with stakeholders and applying professional expertise.

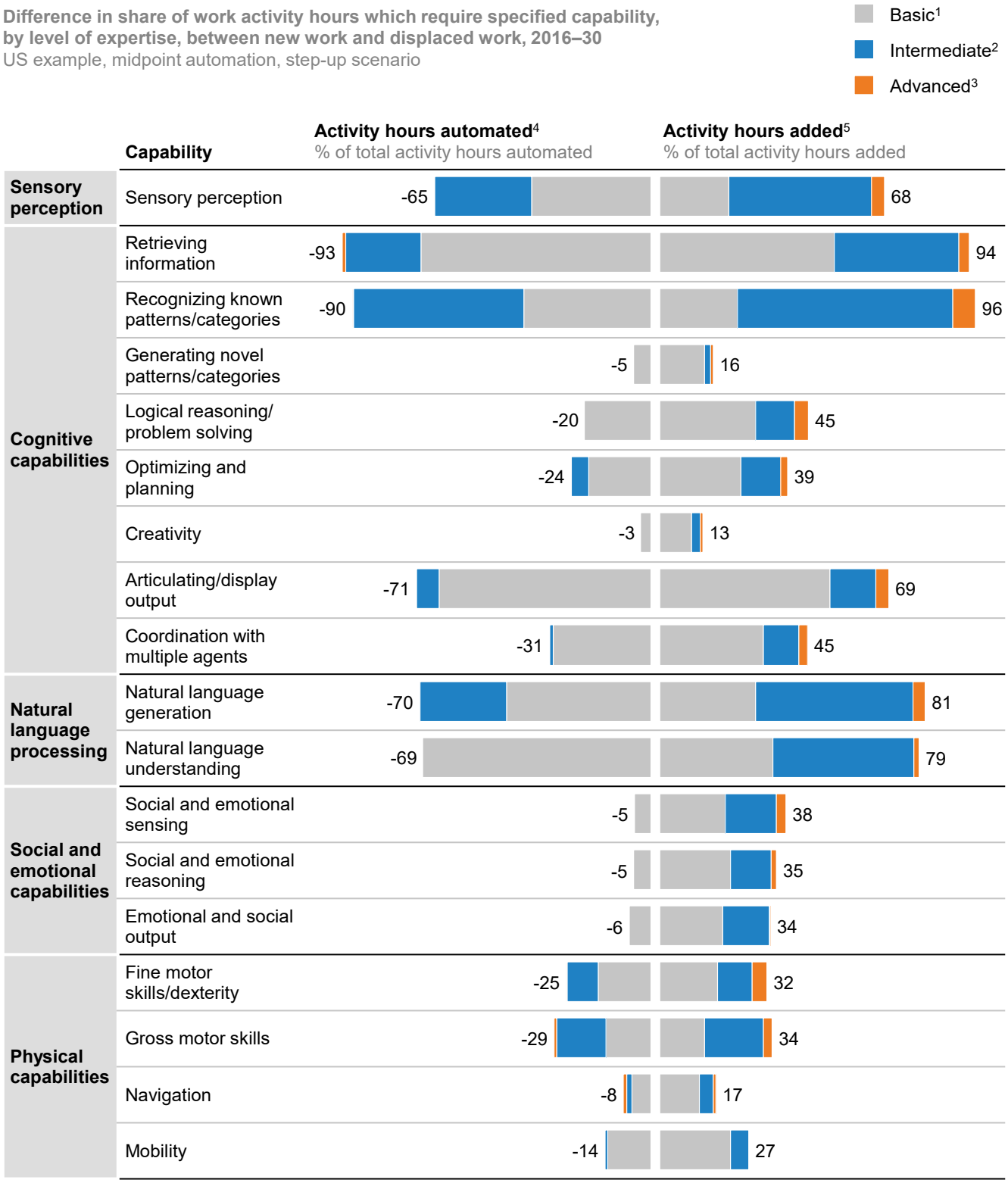
This shifting set of activities has implications for the capabilities that will be needed for future work. Exhibit 20 shows how US workers will need to upgrade their mastery of the 18 performance capabilities we used for our automation modeling.

More work activities will require social and emotional skills and advanced cognitive capabilities, such as high-level logical reasoning—capabilities that are required today for only a relatively limited number of jobs. This will be a challenge for education, training, and skill assessment models, which for now do not always emphasize “soft skills” such as social and emotional reasoning and sensing.

Exhibit 20

Future work activities will require more social emotional, creative, and logical reasoning abilities—and more advanced capabilities across the board

Difference in share of work activity hours which require specified capability, by level of expertise, between new work and displaced work, 2016–30
US example, midpoint automation, step-up scenario



1 Below-median capability required.
2 Median human capability required.
3 At least 75th percentile capability required.
4 80.3 billion activity hours automated (38.6 million jobs).
5 66.3 billion activity hours added (31.9 million jobs).
NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: U.S. Bureau of Labor Statistics; McKinsey Global Institute analysis

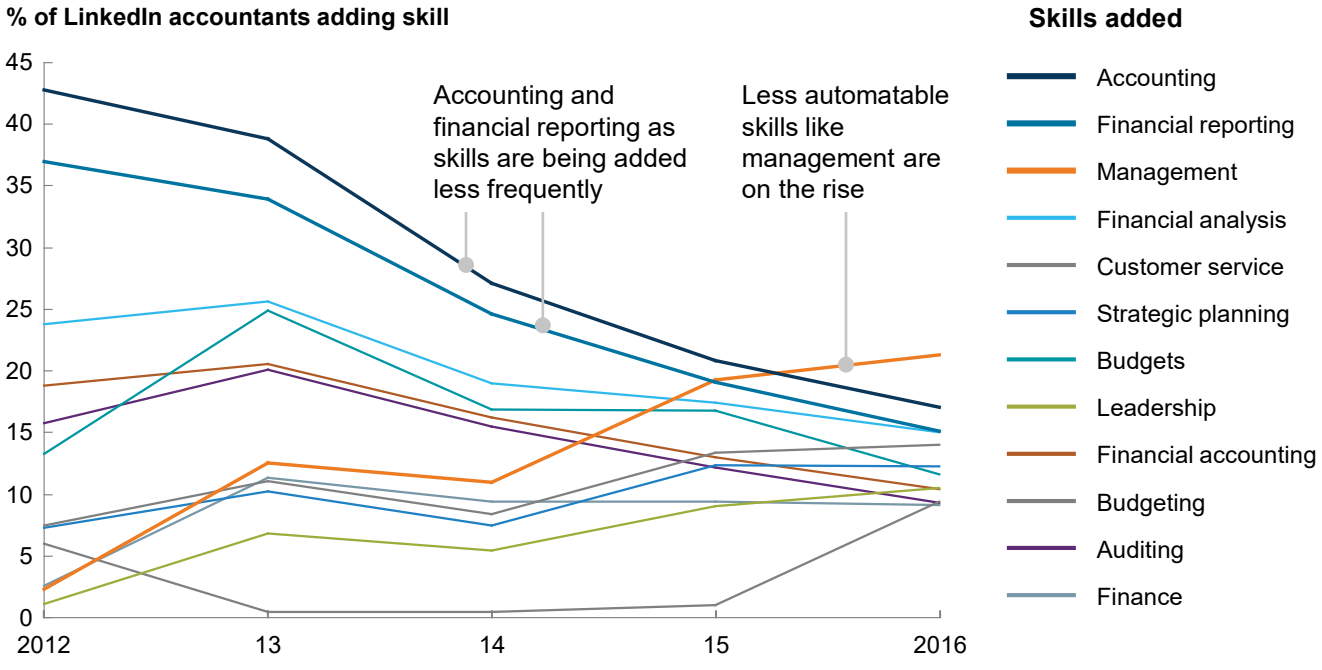
Additional jobs will often require a higher level of performance across many capabilities. For instance, machines will be able to perform work activities requiring basic levels of retrieving information and understanding natural language—but jobs requiring higher levels of these capabilities will grow. In advanced economies, physical capabilities will be less in demand as a percentage of the activity hours demanded in the economy. In developing economies such as India, given the increase in demand for physical activities, demand for physical capabilities will accordingly grow as a percentage of the new activity hours demanded. The shift in activities and underlying capabilities required will touch almost all jobs in the economy, to varying degrees—but especially in advanced economies. As one example, the work of retail salespeople in these economies could change significantly; about 20 percent of their current work activities could be automated in the midpoint scenario. The rote aspects of the job such as processing transactions and gathering product information may be automated. Retail workers instead may turn their attention to the more people-focused side of the job: greeting customers and answering questions, for example, or suggesting new products.

The capability shift is not limited to front-line jobs. Many workers in occupations with high educational requirements who spend much of their time collecting and processing data could experience a significant shift in their work activities. Financial managers, for example, could spend less time monitoring cashflow or approving expenditures, and instead have time to focus on more managerial functions such as supervising employees and advising others on business matters. Professionals of all stripes are quickly realizing the growing importance of "soft skills"—although understanding the implications of numerical calculations will continue to be important. On LinkedIn, the professional networking site, for example, professionals are increasingly developing and marketing themselves around these softer skills, which are less automatable (Exhibit 21).[93]

Exhibit 21

Some indications suggest individuals are highlighting skills that are less susceptible to automation

Accountants on LinkedIn have been prioritizing less automatable skills and deprioritizing more automatable skills
% of ~160,000+ accountants globally on LinkedIn adding specified skills



SOURCE: LinkedIn; McKinsey Global Institute analysis

[93] Data analysis from LinkedIn.

This changing nature of activities and capabilities has important implications for the requirements and aims of job training, which will be particularly relevant in times of transition. For example, as activities requiring basic levels of performance are automated in the United States, training efforts will need to focus on capabilities for which automation is more challenging, such as social and emotional capabilities. Increasingly across occupations, workers will be valued for strong interpersonal skills and advanced reasoning. As these skills are often developed through guided experience, workers will likely spend more time being coached in apprentice-like environments. The workers of the future will still need to apply expertise and judgment, so training to promote fluency with and understanding of information will remain important.

GROWING JOB CATEGORIES HAVE HIGHER EDUCATIONAL REQUIREMENTS THAN THE WORK DISPLACED BY AUTOMATION

Across our six focus countries, a greater share of jobs in the future—accounting for both the effects from automation and the additional labor demand from the seven trends—are likely to demand increased levels of education (Exhibit 22).[94]

Defining and measuring the skills required to perform well in any job is a difficult and imprecise task. In our modeling, we look at several different measures of workforce skills. First, we consider the formal educational requirements of each occupation: secondary school degree, Associate's, Bachelor's, and graduate degrees. Educational requirements by occupation are fairly well standardized globally and allow for cross-country comparisons. However, even within an occupation, there will be a range of degrees that existing workers have obtained; we focus on the educational levels that are typically required.[95] We also look at how activities within occupations will change, which gives some indication of the types of skills that will be more or less in demand, and we consider the capabilities required to perform those activities—such as cognitive skills, creativity, social and emotional skills. Other definitions of skills and credentials are equally valid and important, but are beyond the scope of this report. Many practitioners and researchers today focus on unbundling traditional degrees into well-defined credentials that can be obtained by demonstrating mastery of specific skills. This is particularly attractive for midcareer workers who cannot afford to spend years earning a traditional degree, or who have accumulated valuable experience on the job. Some credentials are for quite narrow skills: programming in a certain computer language, or mastering one specific type of mechanical expertise.[96]

[94] We do not model changing skill requirements for occupations, and assume that educational requirements for an occupation in all countries are the same as in the United States. See technical appendix for details.

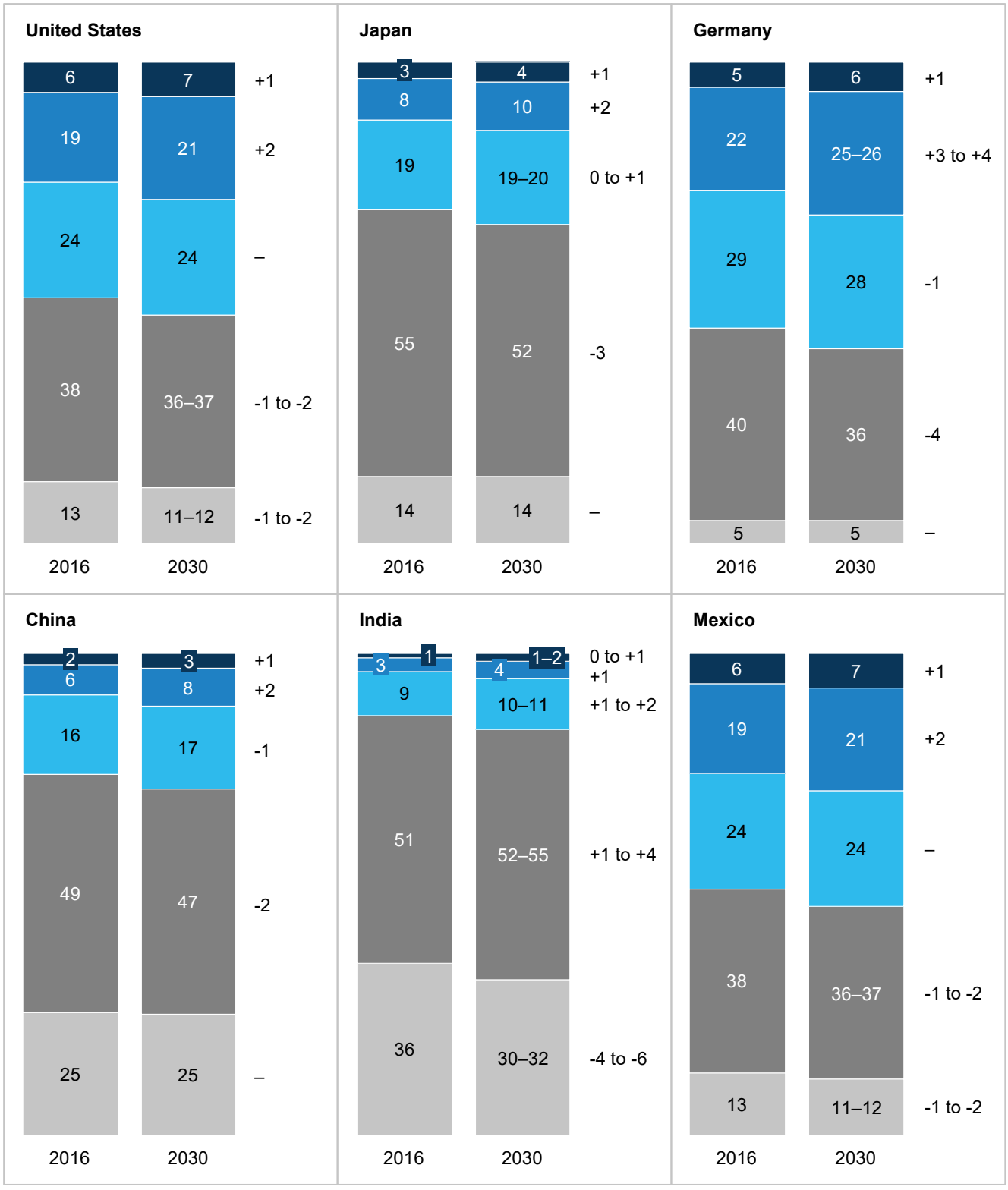
[95] Economists note the general trend of "degree inflation." For instance, in the United States, while 80 percent of job openings for executive assistants list a bachelor's degree as a requirement, fewer than half of existing EAs have that degree. See Peter Capelli, *Will college pay off? A guide to the most important financial decision you'll ever make*, PublicAffairs, 2015.

[96] For a discussion of skills and credentials, see *The narrow ladder: The value of industry certifications*, Burningglass Technologies, October 2007; David Deming et al, "The value of postsecondary credentials in the labor market: An experimental study," *American Economic Review*, 2016; Rajeev Darolia et al., "Do employers prefer workers who attend for-profit colleges? Evidence from a field experiment," *Journal of Policy Analysis and Management*, volume 34, issue 4, fall 2015.

Exhibit 22

Skill requirements for jobs are increasing globally; an increasing percentage of jobs will require college and advanced degrees

Skill requirements, 2016 and 2030, and change
% of sized labor demand; percentage points



NOTE: All figures are projected using the midpoint automation scenario; only includes the sized labor demand (e.g., the creation of new occupations is not included). Some occupational data projected into 2016 baseline from latest available 2014 data. Numbers may not sum due to rounding.

SOURCE: US Bureau of Labor Statistics; McKinsey Global Institute analysis

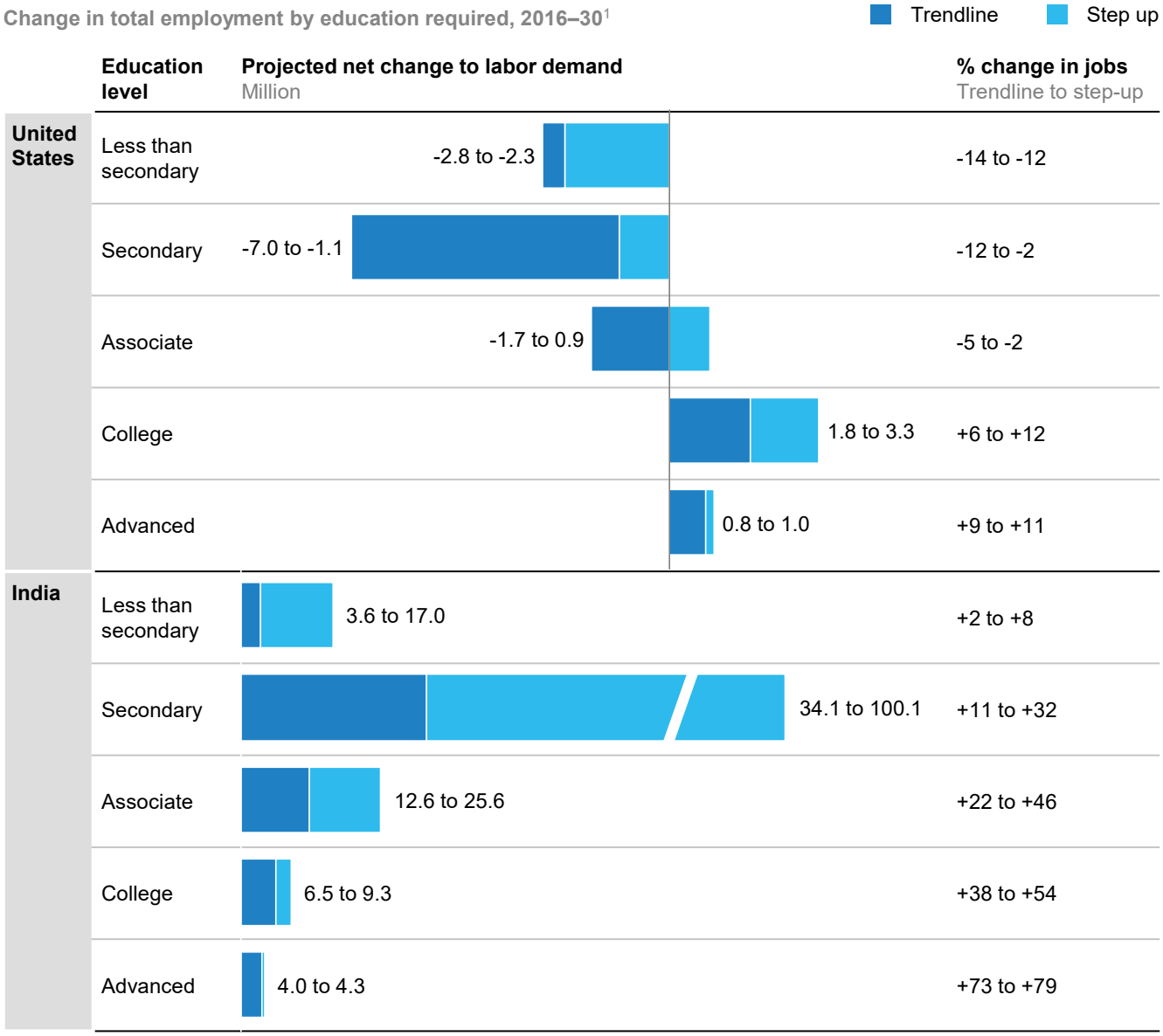
In advanced economies, demand for work currently requiring completion of secondary school or less will likely decline

In advanced economies, our model shows a common pattern of educational requirements. Occupations that currently require only completion of secondary school or less, including jobs such as office clerks, hand packers and packagers, and tellers, are most likely to be affected by automation and have a net reduction in labor demand, based on the factors we have modeled (Exhibit 23).

Exhibit 23

In the United States, occupations with lower educational requirements are declining, while in India, both trendline and step-up scenarios will see large increases in demand for secondary degrees

Change in total employment by education required, 2016–30[1]



1 Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: O*Net skill classification, US Bureau of Labor Statistics; McKinsey Global Institute analysis

Not all jobs in these categories will disappear, but in 2030, demand for the activities they currently perform will be lower in all of our modeled scenarios. In contrast, occupations requiring a college or graduate degree will see the most growth as a percentage of jobs in the economy. Occupations that require training on top of a traditional post-secondary degree (for example, career, technical, vocational training) or two-year associates' degree

have a mixed outlook. As a share of jobs in the economies, countries such as Japan will see increased demand for associates' and equivalent degrees, primarily from middle-skill health-care occupations such as nurses and paramedics. Meanwhile, countries such as Germany will see decreased demand, primarily because of a greater share of automatable office support jobs such as clerks and secretaries.

The relative growth of jobs requiring higher educational attainment is not a new observation.[97] Nor is the increase of skill requirements necessarily a break from historical trend: the manufacturing revolution saw increased need for literacy training that spawned movements toward secondary education including the High School Movement in the United States, which we discuss in the next chapter.

However, many of the middle-income jobs of the past that required only a secondary education or less, and minimal training, will likely face significant displacement in an automated world. These jobs include heavy truck drivers and office clerks, both of which have high technical potential for automation over our modeled time horizon, and whose current middle-level wages raise the economic incentives to deploy automation. Many additional jobs requiring low and middle levels of educational attainment could be created, driven particularly by the caring economy, such as the rise of nurses and nursing assistants. However, for many jobs that require no or only secondary education, the additional future labor demand will not fully make up for the jobs displaced by automation. This would mean that many displaced workers would need to retrain and/or raise their educational levels to gain employment in one of the in-demand occupations.

The seven trends we modeled alone suggest that overall new demand for work currently requiring a college degree could be sufficient to balance the reduction in demand for work activities lost to automation in occupations requiring college completion, in the United States, as well as in Germany (where the net modeled demand for these occupations increases).

However, that does not obviate the need for college and advanced degree holders to retrain, as their activities will change. Some will switch to jobs that require a similar level of educational attainment, but very different skills. The coming wave of technology deployment, bolstered by advances in machine learning and artificial intelligence, has significant potential to automate work activities previously thought to be the exclusive domain of highly-trained humans. In the midpoint automation scenario, 13 percent of the current work activities performed in occupations that require college or advanced degrees in the United States could be displaced. Even within a given field, certain occupations will fare better than others. In the United States, for example, the high-skill job of application software developer has large net additional demand (we model nearly ten times as many jobs created as displaced). Meanwhile certain technology support jobs including computer systems administrators and support specialists may see a cooling of demand, because a substantial portion of their current activities have relatively high technical automation potential. Similarly, in US financial services, the varied skills required of management analysts could see high demand, while financial managers and securities sales agents could face substantial automation of their current work activities with limited sources of new demand.

[97] For example, MIT economist David Autor has credited the trend to productivity boosts from information technology that magnifies the productive power of cognitive functions, which is often central to higher-skill work. Ibid. David H. Autor, "Why are there still so many jobs?" summer 2015. In the United States, about two-thirds of jobs from Baby Boom retirement require more than a secondary school education. Jamie Merisotis, *America needs talent: Attracting, educating, and deploying the 21st century workforce*, Rosetta Books, 2015; see also, Anthony Carnevale et al., "Good jobs that pay without a BA," Georgetown University Center on Education and the Workforce, 2017.

Workers displaced by automation may need to invest time to acquire new skills, either through formal education or other training programs. Conversely, jobs themselves may need to be redesigned to accommodate an influx of new workers with less sector-specific training and overall education. The transitions could be varied and lead to friction in the labor market and potentially higher unemployment in the short-run. But other steps could be taken to make markets function better. For example, defining job requirements, as well as providing training and certification, based on specific skills, could improve the matching of labor supply and demand, as these skills can be much more fine-grained than traditional educational degrees, and can often be acquired in less time than finishing a multi-year degree program.

While some workers who are displaced by automation will be able to find a job in a similar function and with similar educational requirements (for example, a displaced cashier finding a new job as a retail salesperson), many will not, and will need to gain additional skills, which may or may not actually raise their educational level. This is discussed in a subsequent section of this chapter.

Additional job creation in our step-up scenario could help mitigate some of the impact of automation, with additional investment in infrastructure, buildings, and energy transitions potentially creating new work for workers with low and mid-level educational attainment. In all, in the United States, we estimate additional demand for mid-skill labor of up to 1 million jobs, net of automation, in the step-up scenario. Demand for occupations requiring post-secondary education also increases in the step-up scenario. Engineers and cost estimators will be brought in to develop infrastructure projects, for example, and various professionals, from accountants to research analysts, will also see increased demand.

In developing countries, the largest number of new jobs will be those requiring secondary education or technical skills

In emerging economies, the rate of job growth is highest for occupations that require a college degree or more, but the absolute amount of job growth is highest for occupations with a secondary education diploma.

In China, for instance, occupations currently requiring college and advanced degrees will see increased demand—in the case of those with college degrees, this could be as high as 22 million additional net jobs under our step-up scenario. However, the largest absolute number of jobs created—almost 60 million in the step-up scenario—currently require only a secondary school diploma, with significant increased demand for retail salespeople, nursing assistants, childcare workers and others according to our analysis. Despite the dual threat of automation (particularly for manufacturing, which makes up about 19 percent of employment in China) and other increasing productivity, significant demand will be created for lower-skill work, primarily due to rising prosperity. Also, jobs with low educational attainment requirements in these countries are generally lower wage, and are thus less economically attractive to automate.

India, meanwhile, will see the largest new demand net of automation for workers with a secondary education. According to our analysis, as many as 100 million new jobs could be created for Indians with secondary education—even after accounting for the effect of automation—as rising prosperity will create a surge of new labor demand for construction, retail, and health care and education jobs, among others. The largest countries in the developing world, in short, should not have a shortage of labor demand across any education level, but the significant increase in work requiring completion of secondary education indicates a need for India to upgrade its school system.[98]

[98] In 2011, only 40 percent of Indian adolescents attended secondary school (Grades 9-12), compared to more than 95 percent who attended primary school. The World Bank, *Education in India*, September 20, 2011.

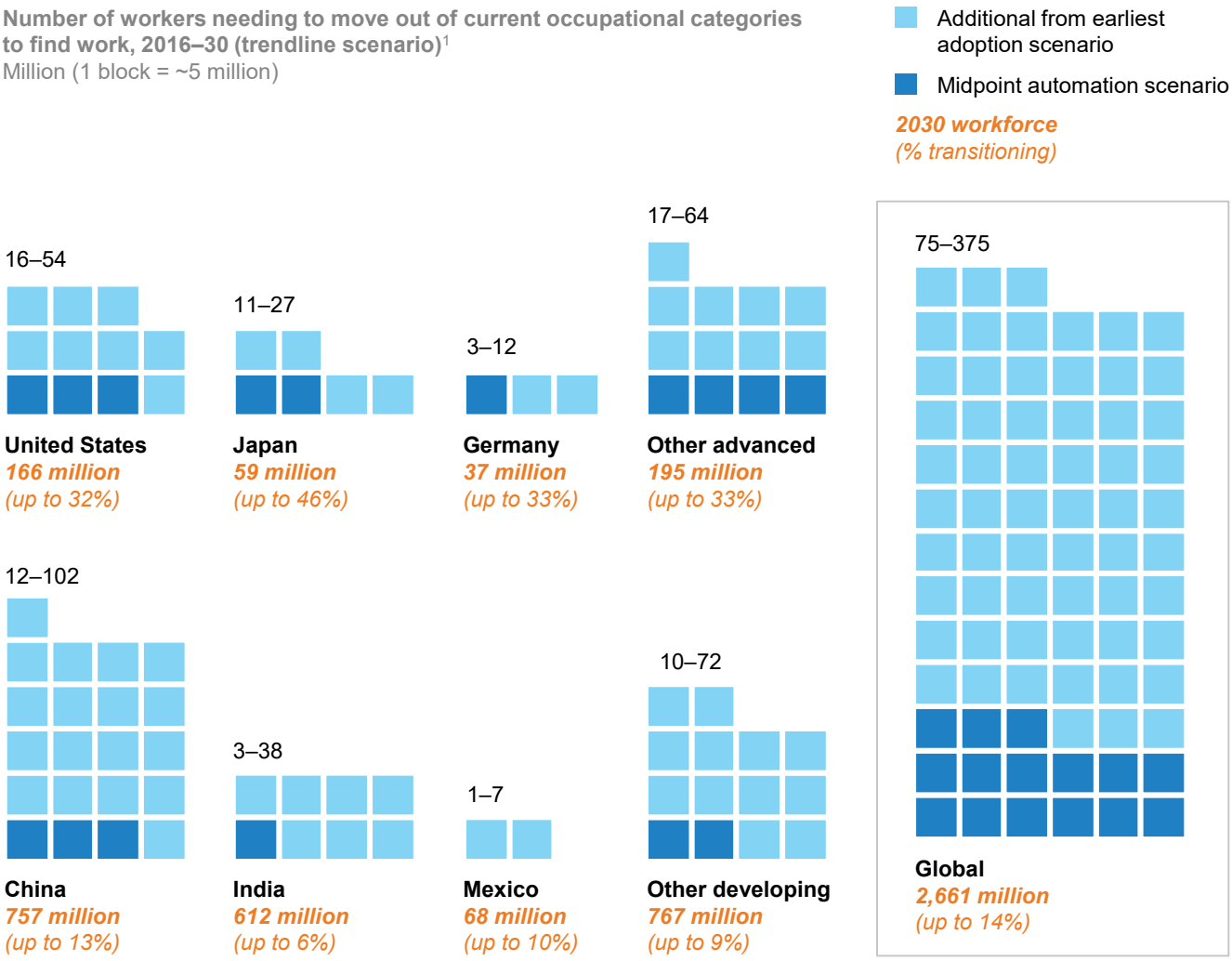
TENS OF MILLIONS OF INDIVIDUALS GLOBALLY WILL NEED TO SWITCH OCCUPATIONAL CATEGORIES, AND MAY REQUIRE TRAINING TO DO SO

Our findings shed some light on the potential size of the worker transitions that will be necessary in the years to 2030—and the immense training efforts that will be necessary as the nature of some work changes. We estimate that up to 75 million workers may have to switch occupational categories and/or educational levels in the midpoint automation scenario (Exhibit 24).[99] If automation technologies are developed and adopted sooner, those numbers grow rapidly; in the earliest automation adoption scenarios that we analyze, as many as 375 million people may need to change occupational categories and/or educational levels. However, our step-up scenarios reduce our estimates of the number of people needing to make these types of transitions, with additional labor demand trends offsetting more job displacement from automation within occupational categories. Not shown on the exhibit, in the slowest automation scenario, the number of required transitions is significantly reduced (almost negligible in most countries).

Exhibit 24

Globally, up to 375 million workers may need to switch occupational categories

Number of workers needing to move out of current occupational categories to find work, 2016–30 (trendline scenario)[1]
Million (1 block = ~5 million)



1 Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: U.S. Bureau of Labor Statistics; McKinsey Global Institute analysis

[99] Analysis conducted by segmenting all US Bureau of Labor Statistics occupations into 58 occupational categories. See technical appendix for details.

Some of these people who are displaced will seek new education and many will need new skills. People will also need to learn new skills within their occupations as activities change, particularly where those activities are augmented by automation. As a point of calibration, in our rising incomes trend, we project that between 190 million and 205 million students will be in tertiary education in 2030.[100] In the fastest automation scenario that we model, the number of people that will need to transition between 2016 and 2030 is almost double that number.

These transitions could surface frictions in the labor market, for reasons ranging from lower wages to cultural and gender bias, but also present new opportunities for work and job growth. For example, men could find opportunities to retrain into jobs in which women have dominated in some countries, such as nursing in the United States, and vice versa.[101]

WAGE POLARIZATION MAY CONTINUE IN SOME ADVANCED ECONOMIES

Middle-wage jobs have felt the impact of automation in the past decades in the United States, creating a polarization phenomenon. Modeling the potential impact of automation, we find that this polarization could continue and become exacerbated in advanced economies—but not universally. Indeed, one of our findings is that the potential wage impact of automation and future labor demand could vary considerably among countries. We also find that any polarization of wages is not due solely to skill gaps; some of the additional demand for middle-skill jobs are in those that are currently paid low wages in countries such as the United States.

In advanced economies, high-wage occupations see the most growth net of automation

Academic literature examining the recent impact of technology on wages has found that a distinct pattern of "hollowing" or a decline in middle-skill and middle-wage jobs with growth in high- and low-wage occupations (see Box 5, "Our prior research on income and equality trends").[102]

Our analysis is based on current average wages for each occupation in each country. Modeling wages over time by occupation based on the dynamics of labor supply and demand is outside the scope of this study, beyond the top-down analysis of wage impact that we described in the previous chapter. Nonetheless, our examination of job growth at different current wage levels offers some indications of what the future may hold.

In the United States and Germany, in our trendline labor demand and midpoint automation scenarios, occupations in the top 30 percent of average current wages experience net job growth by 2030 (Exhibit 25). This holds for the United States even in the modeled step-up scenario; in the step-up scenario for Germany, rising need for jobs such as nursing assistants is expected to increase demand for middle-wage jobs. The largest declines are in jobs in the middle of the wage distribution. Occupations in the lowest 30 percent of wages decline, but this reflects the net impact of modest growth in low-wage occupations such as retail salespeople, and declining occupations such as hand packers/packagers and cafeteria cooks.

---

[100] Based on analysis conducted with World Bank tertiary education data.

[101] Our analysis suggests that future labor demand on an aggregate basis will not have a gender bias. Automation overall will affect jobs that are traditionally male-dominated, as in manufacturing, but also jobs that are traditionally female-dominated, such as food services or accommodation. New jobs with a traditional male bias such as construction work will be created, as will jobs such as nurses that have traditionally been dominated by women.

[102] Harry Holzer, *Job market polarization and U.S. worker skills*, April 2015; and Ibid. David H. Autor, "Why are there still so many jobs?" summer 2015.

Box 5. Our prior research on income and equality trends

The trends we identify in this report for both low- and middle-wage jobs and high-wage, high-skill jobs overlap with some of the structural shifts in the labor market in the past few decades that we have examined in prior reports. Among our findings:

"Superstar" effects and the hollowing of the middle. Digitization has already affected the occupational and skill mix of the US workforce. Since the 1980s, employment in both low-skill and high-skill jobs has increased, while middle-skill jobs have declined. With many routine production and assembly tasks being automated, most of the growth at the low-skill end of the spectrum has been in occupations such as restaurant workers, home health-care aides, security guards, maintenance workers, and other roles that provide in-person services that are less susceptible to automation. At the same time, idea-intensive sectors have been capturing a larger share of the overall corporate profit pool. There is now a premium on creative and cognitive tasks that improves overall productivity of highly skilled workers. The result is an increasingly two-tiered labor market.[1]

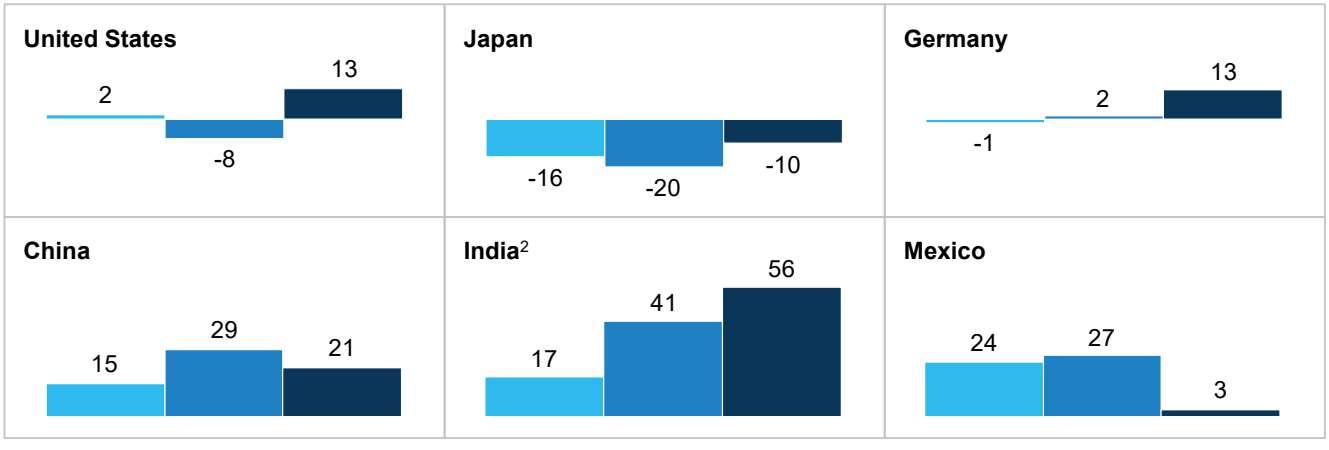
Flat and falling incomes in advanced economies. With only occasional exceptions, most income groups in advanced economies have experienced steady income advancement since World War II, but that changed abruptly in the past decade. Between 2005 and 2014, our research found that about two-thirds of income groups had either flat or falling market income (wages and capital), although in some countries including the United States government taxes and transfers cushioned the blow for disposable income. While economic recession and slow recovery after the global financial crisis were a primary cause, other long-run factors—including a decline in the wage share of GDP, aging, and shrinking household size—will continue to weigh on incomes in the future. The decline in wage share has taken place despite rising productivity, suggesting that productivity and incomes have become disconnected. The distribution of this wage share among different income segments has also been uneven: since 1993, households in the uppermost income segments in the countries we looked at received a growing share of the total wages, even as the share for low- and middle-income segments has either stagnated or fallen.[2]

1 Ibid. *Digital America*, McKinsey Global Institute, December 2015.
2 *Poorer than their parents? Flat or falling incomes in advanced economies*, McKinsey Global Institute, July 2016.

Exhibit 25

Generally, high-wage jobs show the most positive percentage change in advanced economies, while mid-wage jobs fare best in emerging economies

Net job change by tercile, step-up scenario, 2016–30
% ± change in labor supply due to automation and labor demand catalysts[1]



1 Midpoint of earliest and latest automation adoption.
2 Low-wage group for India includes all production occupations (~45% of total population).
NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: ONET skill classification, US Bureau of Labor Statistics; McKinsey Global Institute analysis

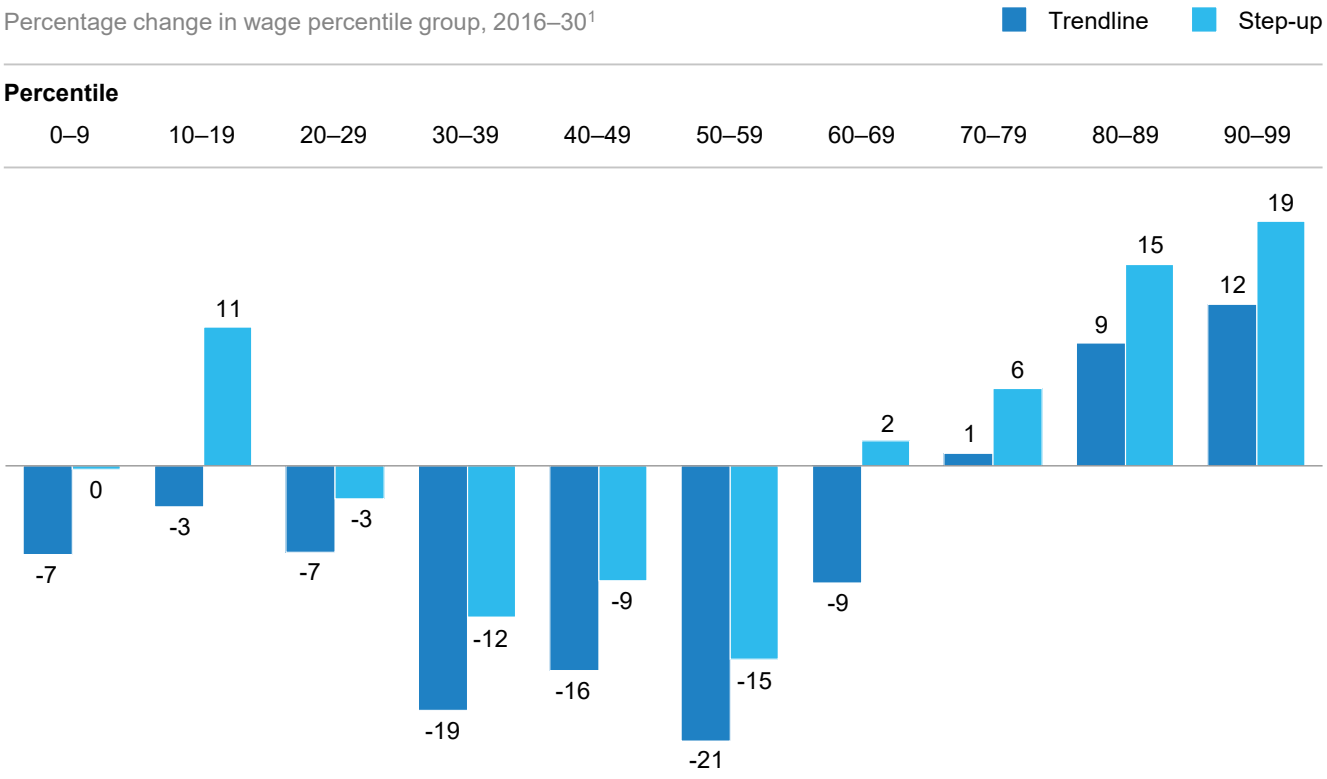
In the United States, the pattern of polarization is clearer if we look at the net job growth by wage decile (Exhibit 26). The top two deciles experience significant new demand for labor net of automation, primarily driven by an increase in demand for high-skill professionals, including technology and medical professionals. The effects of aging and, in the step-up scenario, professionalization of unpaid work also create growth at the lower end of the wage spectrum, around the 20th percentile. This is driven by growth in nursing assistants, teaching assistants, and personal care aides, among others.

In our model, the step-up scenario involving increased spending on such areas as infrastructure, real estate, and energy transitions can help create more growth in middle-wage (as well as low-wage) jobs. For example, in the United States, increased infrastructure and real estate spending can create additional demand for labor in construction, skilled craftspeople, and technical production jobs, which are middle-wage jobs. The increased professionalization of unpaid services would also add jobs for middle-wage work in countries like Germany through increased demand for nursing assistants and childcare workers. These types of jobs could help produce some of the additional labor demand to offset activities that could be automated, in particular, providing demand for middle-wage jobs in advanced economies.

Exhibit 26

In the United States, high wage jobs see the most growth and middle wage jobs decline the most

Percentage change in wage percentile group, 2016–30[1]



1 Numerator: net change; denominator: 2030 scaled FTE in the given wage percentile bucket. Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: McKinsey Global Institute analysis

In developing countries, middle-wage occupations could experience strong growth

The potential wage trend picture is quite different in emerging economies. In India, occupations at all wage levels are boosted by demand from rising prosperity, while the economy will largely be shielded from automation because of lower wages. In China, our scenarios show that middle-wage jobs will rise similarly. Across both countries, the main occupations that are driving this growth in middle-wage jobs involve customer interaction. Job growth is particularly pronounced for cashiers and retail salespeople, which are middle-wage jobs in these markets. While in the developed world many of these jobs may be automated, in India and China, wages are low enough that automation rates will likely be constrained in the 2030 timeframe (modeled at under 10 percent). The story is a positive one for wage advancement and the development of the middle class: in India, for example, if farmworkers (with annual salary of $1,752) find themselves out of a job because of productivity improvements, many new and more highly-paid services jobs will sprout up in hosting (average wage of $2,204), and for retail salespeople ($4,101).

In these developing countries, the challenge will be to continue to create more high-wage work opportunities for high-skill workers, and move a greater proportion of workers into higher wage jobs. While India will have high demand for high-wage work, this type of work in China is more susceptible to automation compared with other developing countries, according to our model, primarily because of higher wage rates. Computer support specialists and law clerks, two high-wage occupations, have an automation potential in the midpoint adoption scenario of 34 percent and 35 percent, respectively. Overall, then, while developing countries may have less to worry about when it comes to creating labor demand to offset the effects of automation in the near term, policy makers and business leaders may want to focus on the creation of more gainful and desirable employment.[103]

•••

Work will change in the next decade and beyond, with significant implications both for skill requirements and wages. While our research suggests that these trends will play out differently among countries, some commonalities are apparent. One is that educational requirements and performance capabilities, including for soft skills such as social and emotional reasoning, will become ever more important. In advanced economies including the United States, middle-wage workers could continue to see a shrinking pool of opportunities as automation outpaces new job creation. As many as 375 million individuals around the world will need to switch occupational categories. Providing retraining opportunities at scale will be imperative. What should the policy priorities be in this changing workplace? In the following chapter, we look at how the transitions brought about by automation can best be managed.

[103] Ibid. *India's labor market*, McKinsey Global Institute, June 2017.

THE FUTURE OF WORK BY COUNTRY

In the following section, we highlight scenarios for the future of work in our six focus countries: China, Germany, India, Japan, Mexico, and the United States. The charts show a range of possible outcomes for jobs displaced by automation adoption to 2030 and scenarios for future jobs that could be created by seven catalysts of labor demand, as well as by new occupations that could arise. For the automation of work, we consider scenarios based on the speed of adoption of automation technologies. For potential labor demand, we model a trendline scenario based mainly on past experience, and a step-up scenario that considers, among other things, increased investment in infrastructure, buildings, and energy efficiency that countries may choose to make. Based on the net impact of automation versus future labor demand growth by occupation, we estimate the number of workers who may need to change occupational categories, and the possible implications for educational attainment and wages.

These charts should not be taken as forecasts or predictions. Rather, they illustrate a range of possible outcomes. The scenarios we assess in this report may overstate or understate the actual impact of automation on work and future labor demand. For example, if automation adoption is more rapid than even our earliest adoption scenario, this could mean that more work would be automated than we estimate. On the other hand, automation might boost productivity growth more than we have modeled, and this could lead to stronger aggregate demand growth and more job creation across the economy than we have modeled. Box E2 on page 21 discusses the many factors that could change our results for any individual country.

China

China's shift out of agriculture into manufacturing and services is likely to continue and, as incomes continue rising, consumption will increase. With its aging and shrinking workforce, China will benefit from embracing automation to increase productivity and meet projected 2030 labor needs.

Economics and demographic context

Demographics

9% over 65 years of age in today's population, and growing to 17% by 2030

Economic development

5.5% GDP per capita growth, annualized 2016–30

Wages

$10,500
average annual wage

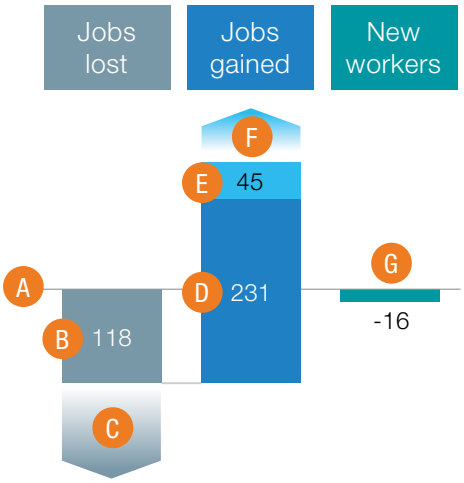
Automation potential

16% of current work activity hours automated by 2030
in the midpoint scenario, and up to 31% in the rapid scenario

Jobs lost, jobs gained

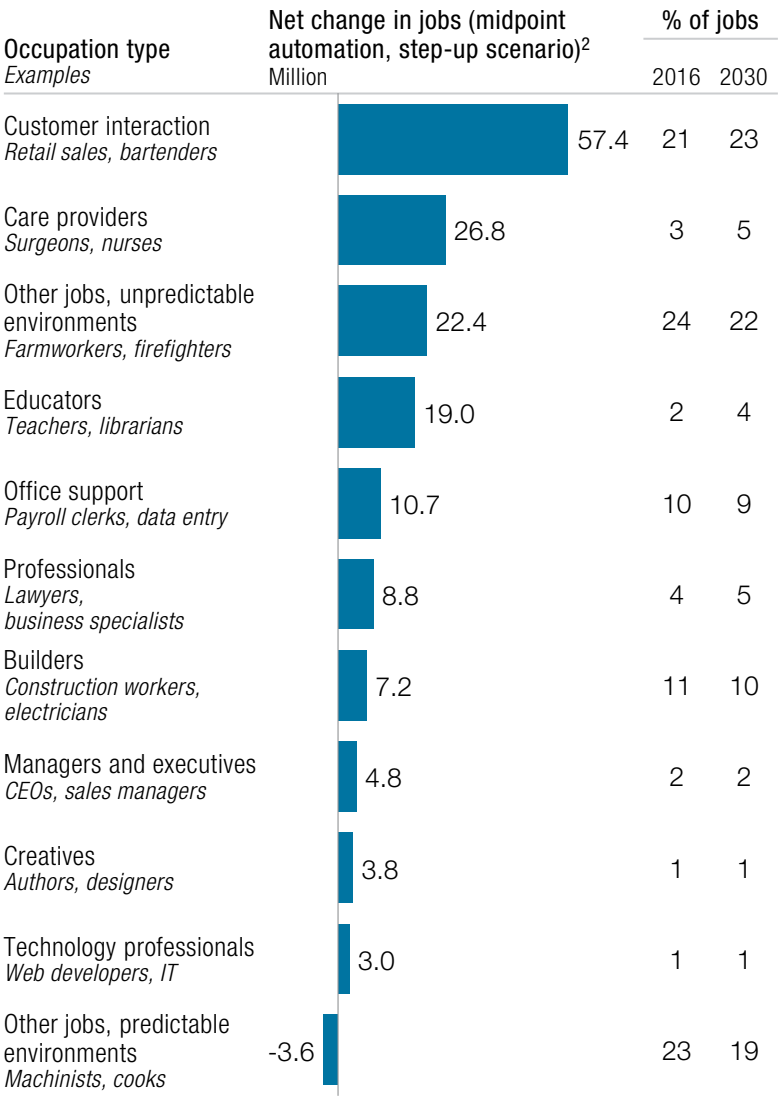
Net change in jobs by 2030 (Million)

Enough jobs are created in the trendline scenario to offset effects of automation and the decline in labor force



- A 2016 baseline
- B Jobs displaced by automation by 2030 in the midpoint scenario
- C Jobs displaced by automation by 2030 in the rapid scenario
- D Jobs created by 2030 in the trendline scenario
- E Jobs created by 2030 in the step-up scenario
- F New occupations and unsized labor demand[1]
- G Change in labor force by 2030

Growth/decline of occupation types by 2030



1 Historical analysis suggests that we could expect 8-9% of 2030 labor supply will be in "new jobs" relative to today, which is additional to what we have estimated.

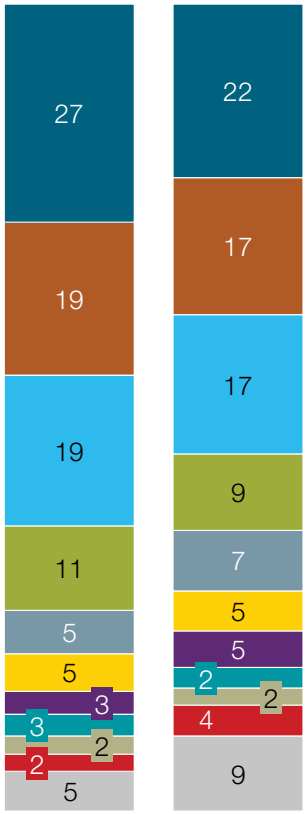
NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: McKinsey Global Institute analysis

Sector and occupation shifts

With automation and the labor demand catalysts, workers may need to switch occupations

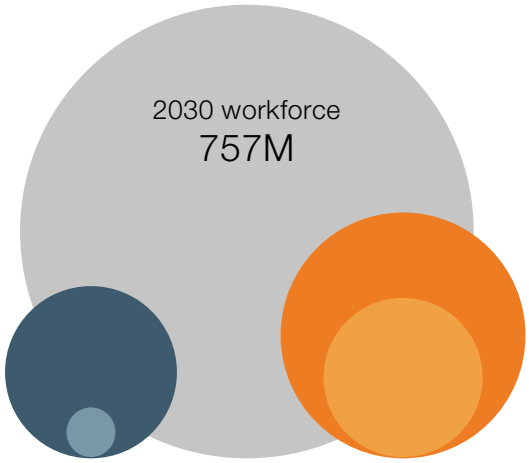
Sector share of labor force (%)[1]



Additions, net of automation (Million)

Agriculture	-18
Manufacturing	+5
Retail and wholesale trade	+12
Construction	-6
Other services	+22
Education	+8
Accommodation and food services	+20
Finance	+2
Transportation	+2
Health care	+15
Other	+51

Number of workers displaced by automation, and those needing to change occupational categories[2]

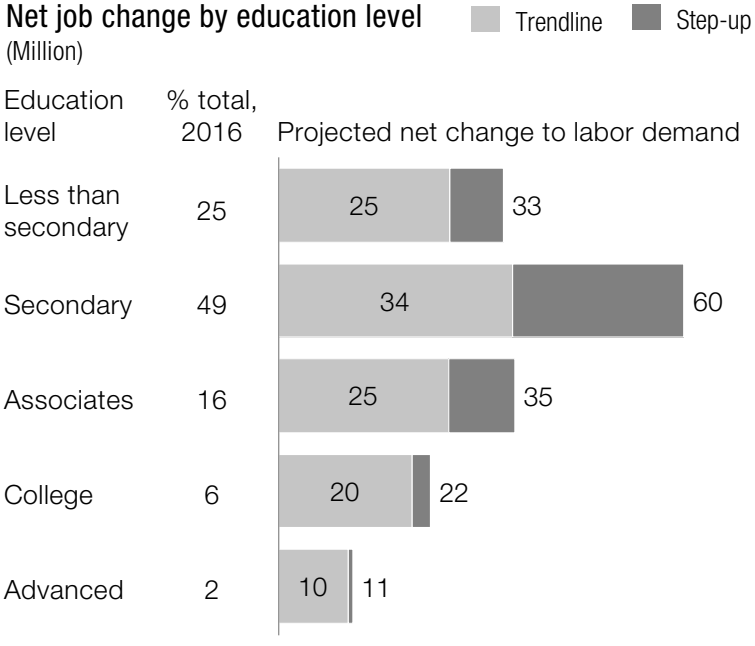


Midpoint automation	Rapid automation
118M displaced	236M displaced
7M–12M changing occupations	82M–102M changing occupations

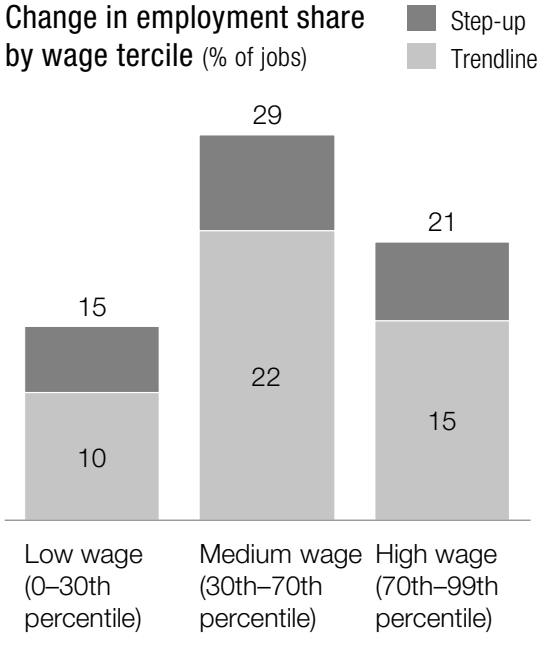
Up to 13% of the 2030 workforce may need to switch occupational groups

Job change by education and wage level, 2016–30[3] (midpoint automation)

Net job change by education level (Million)



Change in employment share by wage tercile (% of jobs)



1 Step-up scenario, midpoint automation, not all sectors modeled in labor demand catalysts (e.g., government).
2 "Transition" = switch occupation groups or gain new skills. Numbers given are trendline – step-up scenario.
3 Educational analysis based on current educational requirements. Employment analysis based on current wages.
NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.
SOURCE: McKinsey Global Institute analysis

Germany

Germany has an aging population and a declining working-age population. Relatively high wages make a stronger case for early automation adoption, while medium GDP growth creates sufficient labor demand in most scenarios. Health-care needs from aging and increased consumer spending will drive most job creation.

Economics and demographic context

Demographics

21% over 65 years of age in today's population, and growing to 28% by 2030

Economic development

1.6% GDP per capita growth, annualized 2016–30

Wages

$38,600
average annual wage

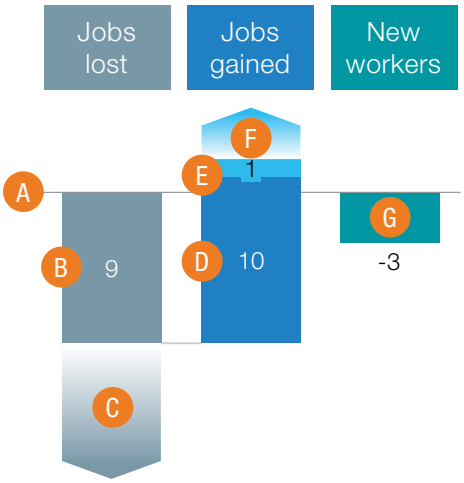
Automation potential

24% of current work activity hours automated by 2030
in the midpoint scenario, and up to 47% in the rapid scenario

Jobs lost, jobs gained

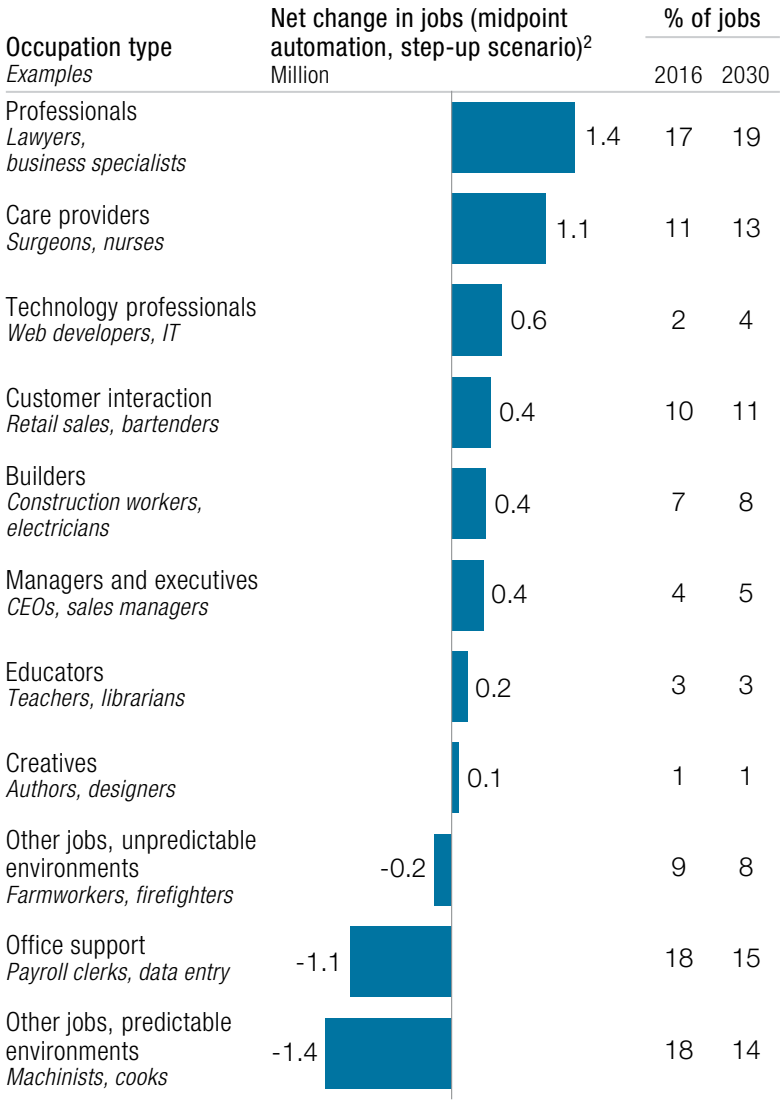
Net change in jobs by 2030 (Million)

Enough jobs are created in the trendline scenario to offset effects of automation and the decline in the labor force



- A 2016 baseline
- B Jobs displaced by automation by 2030 in the midpoint scenario
- C Jobs displaced by automation by 2030 in the rapid scenario
- D Jobs created by 2030 in the trendline scenario
- E Jobs created by 2030 in the step-up scenario
- F New occupations and unsized labor demand[1]
- G Change in labor force by 2030

Growth/decline of occupation types by 2030



1 Historical analysis suggests that we could expect 8-9% of 2030 labor supply will be in "new jobs" relative to today, which is additional to what we have estimated.

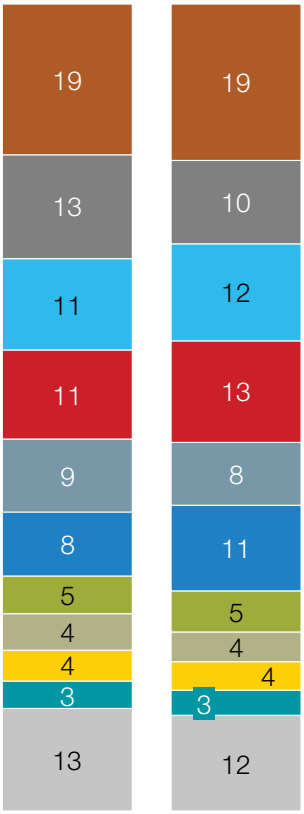
NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: McKinsey Global Institute analysis

Sector and occupation shifts

With automation and the labor demand catalysts, workers may need to switch occupations

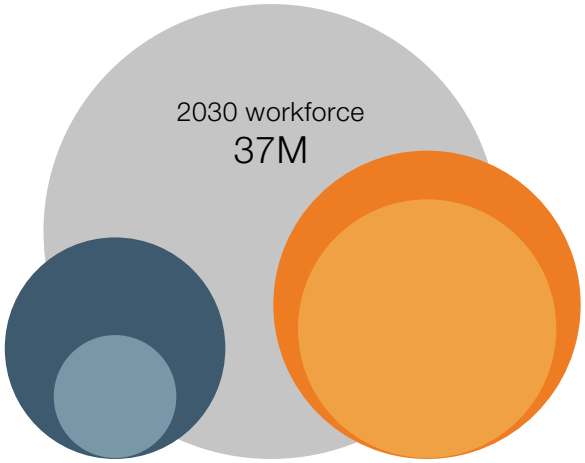
Sector share of labor force (%)[1]



Additions, net of automation (Million)

Manufacturing	+1
Government	-1
Retail and wholesale trade	0
Health care	+1
Other services	0
Professional services	+1
Construction	0
Transportation	0
Education	0
Finance	0
Other	0

Number of workers displaced by automation, and those needing to change occupational categories[2]



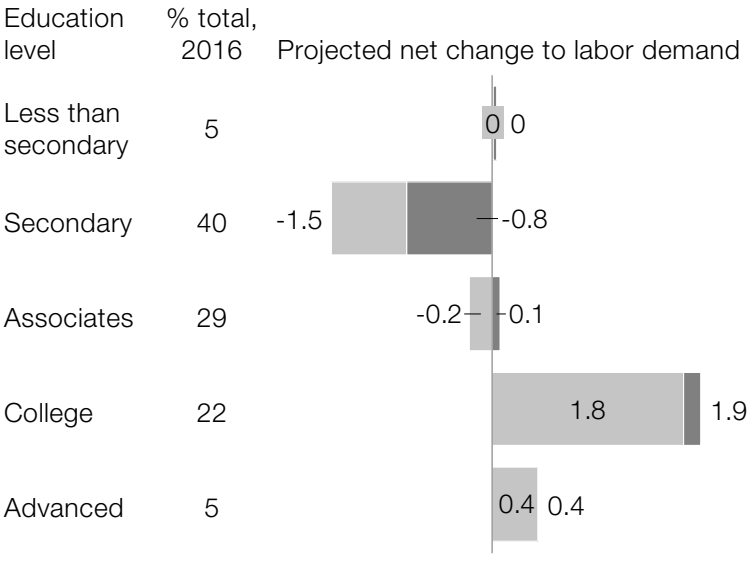
Midpoint automation	Rapid automation
9M displaced	17M displaced
3M changing occupations	12M changing occupations

Up to 32% of the 2030 workforce may need to switch occupational groups

Job change by education and wage level, 2016–30[3] (midpoint automation)

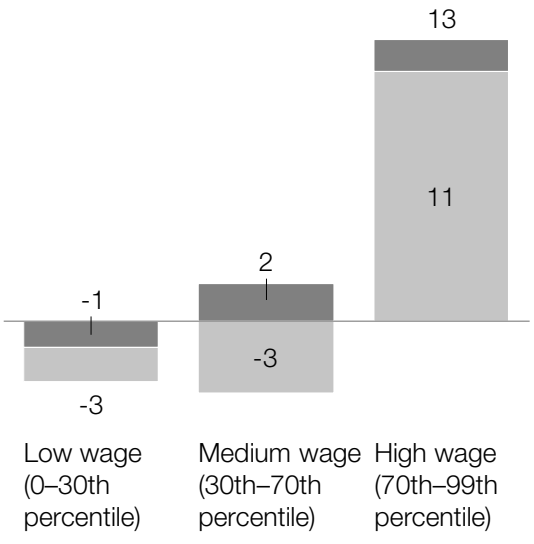
Net job change by education level (Million)

Trendline Step-up



Change in employment share by wage tercile (% of jobs)

Step-up Trendline



1 Step-up scenario, midpoint automation, not all sectors modeled in labor demand catalysts (e.g., government).
2 "Transition" = switch occupation groups or gain new skills. Numbers given are trendline – step-up scenario.
3 Educational analysis based on current educational requirements. Employment analysis based on current wages.
NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.
SOURCE: McKinsey Global Institute analysis

India

India is expected to continue industrializing as its economy shifts away from agriculture. As GDP per capita continues to expand amid rapid growth of the labor force, many of India's jobs of the future will be driven by construction and the consumption habits of the expanding middle class.

Economics and demographic context

Demographics

5% over 65 years of age in today's population, and growing to 8% by 2030

Economic development

5.4% GDP per capita growth, annualized 2016–30

Wages

$4,800
average annual wage

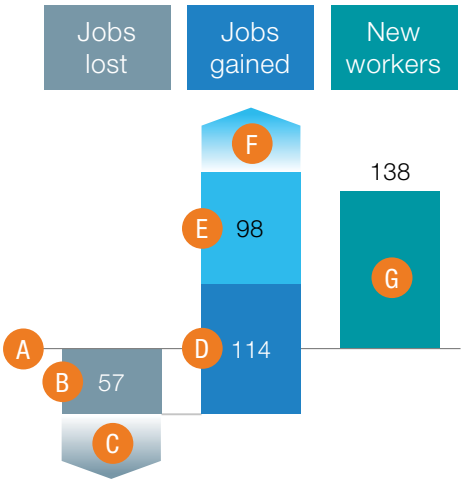
Automation potential

9% of current work activity hours automated by 2030
in the midpoint scenario, and up to 19% in the rapid scenario

Jobs lost, jobs gained

Net change in jobs by 2030 (Million)

Enough jobs are created in the step-up scenario to offset both automation and the growth in labor force



- A 2016 baseline
- B Jobs displaced by automation by 2030 in the midpoint scenario
- C Jobs displaced by automation by 2030 in the rapid scenario
- D Jobs created by 2030 in the trendline scenario
- E Jobs created by 2030 in the step-up scenario
- F New occupations and unsized labor demand[1]
- G Change in labor force by 2030

Growth/decline of occupation types by 2030

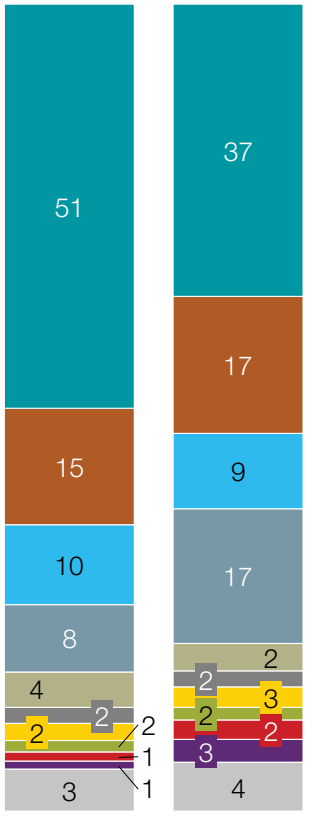
Occupation type *Examples*	Net change in jobs (midpoint automation, step-up scenario)[2] Million	% of jobs 2016	 2030
Builders *Construction workers, electricians*	60.0	11	18
Other jobs, predictable environments *Machinists, cooks*	28.3	30	27
Customer interaction *Retail sales, bartenders*	22.7	10	11
Care providers *Surgeons, nurses*	12.8	1	3
Other jobs, unpredictable environments *Farmworkers, firefighters*	10.8	40	32
Educators *Teachers, librarians*	8.0	1	2
Managers and executives *CEOs, sales managers*	5.9	2	2
Office support *Payroll clerks, data entry*	3.0	3	3
Professionals *Lawyers, business specialists*	2.8	1	1
Technology professionals *Web developers, IT*	1.2	0	0
Creatives *Authors, designers*	0.6	0	0

1 Historical analysis suggests that we could expect 8-9% of 2030 labor supply will be in "new jobs" relative to today, which is additional to what we have estimated.
NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.
SOURCE: McKinsey Global Institute analysis

Sector and occupation shifts

With automation and the labor demand catalysts, workers may need to switch occupations

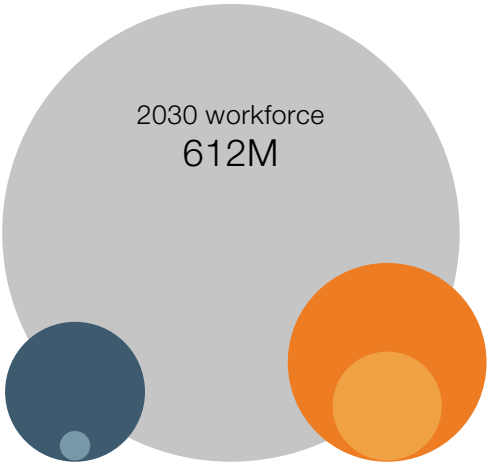
Sector share of labor force (%)[1]



Additions, net of automation (Million)

Agriculture	-16
Manufacturing	+41
Retail and wholesale trade	+11
Construction	+71
Transportation	+1
Government	+2
Education	+6
Finance	+3
Health care	+11
Accommodation and food services	+14
Other	+12

Number of workers displaced by automation, and those needing to change occupational categories[2]

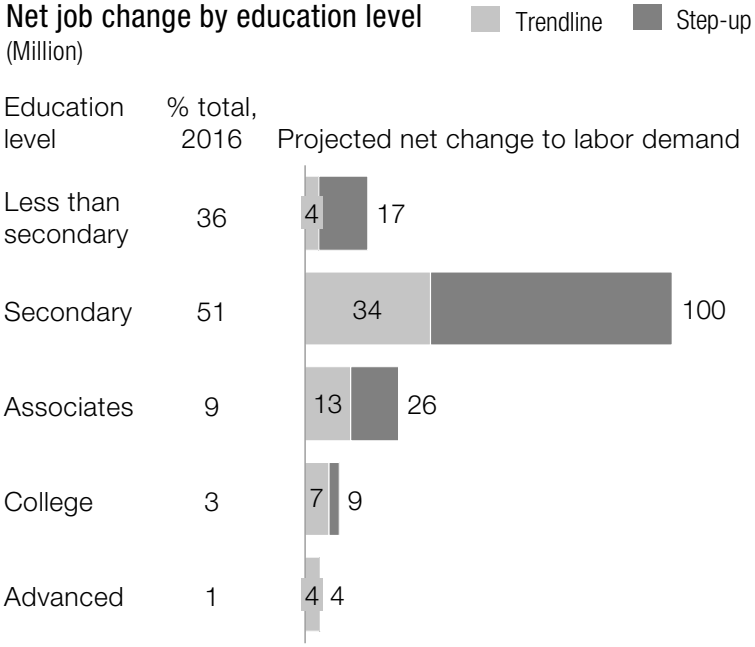


Midpoint automation	Rapid automation
60M displaced	120M displaced
2M–3M changing occupations	18M–38M changing occupations

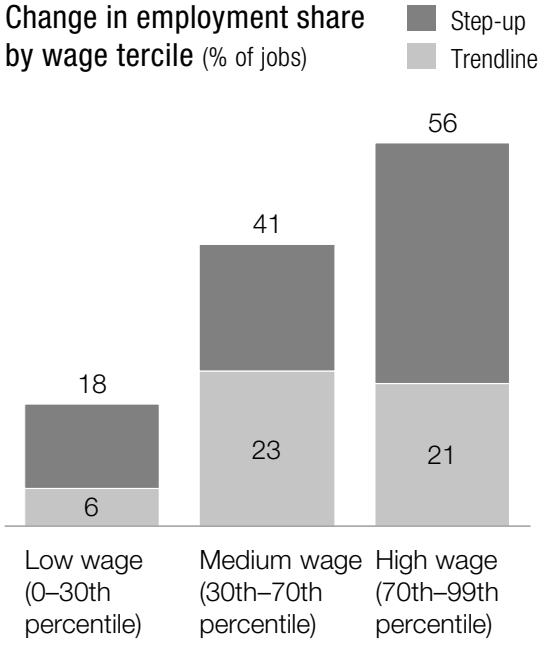
Up to 6% of the 2030 workforce may need to switch occupational groups

Job change by education and wage level, 2016–30[3] (midpoint automation)

Net job change by education level (Million)



Change in employment share by wage tercile (% of jobs)



1 Step-up scenario, midpoint automation, not all sectors modeled in labor demand catalysts (e.g., government).
2 "Transition" = switch occupation groups or gain new skills. Numbers given are trendline – step-up scenario.
3 Educational analysis based on current educational requirements. Employment analysis based on current wages.
NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.
SOURCE: McKinsey Global Institute analysis

Japan

Japan's sector mix and relatively high wages will speed automation adoption, while relatively slow GDP per capita growth could dampen labor demand. The decline in the working-age population will act as a countervailing force, but a step-up scenario of job creation will be needed to sustain future employment.

Economics and demographic context

Demographics

26% over 65 years of age in today's population, and growing to 30% by 2030

Economic development

1.0% GDP per capita growth, annualized 2016–30

Wages

$31,300
average annual wage

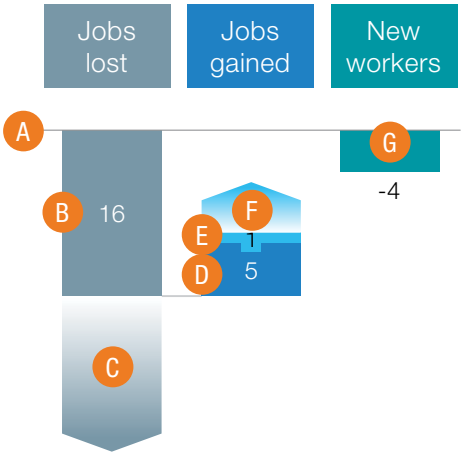
Automation potential

26% of current work activity hours automated by 2030
in the midpoint scenario, and up to 52% in the rapid scenario

Jobs lost, jobs gained

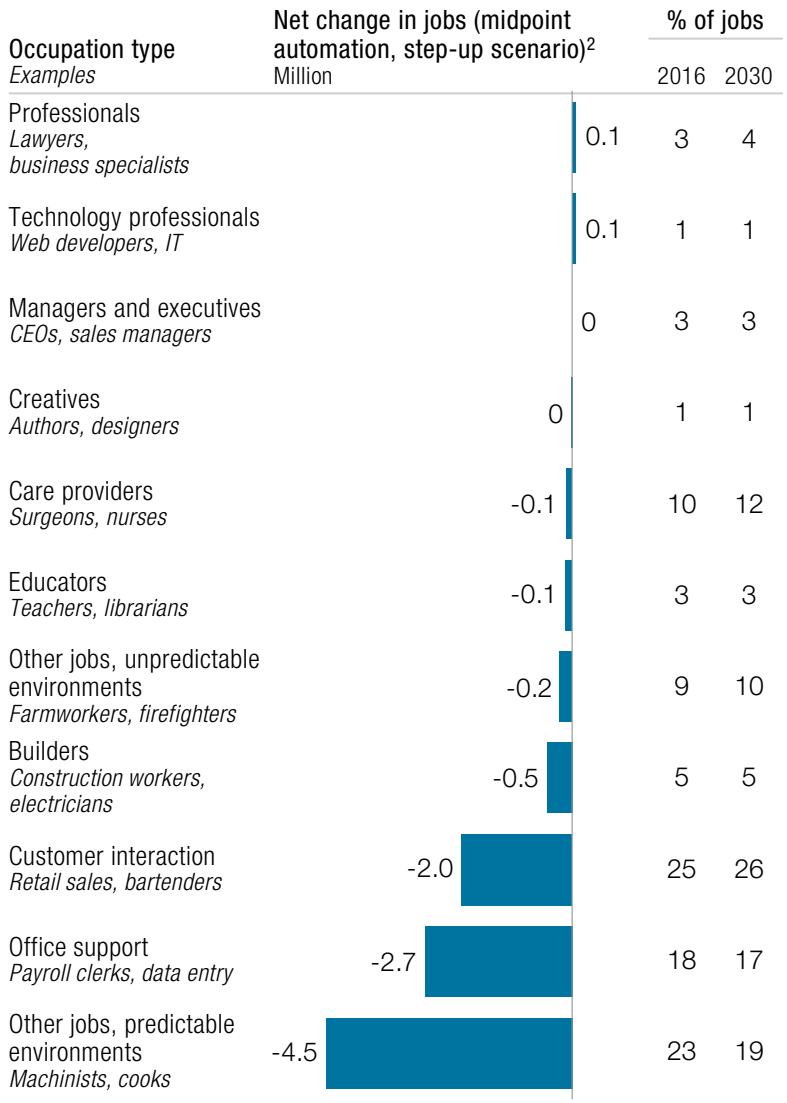
Net change in jobs by 2030 (Million)

Enough jobs are created in the step-up scenario to offset automation and the decline in the labor force, if innovation creates sufficient new work activities



- A 2016 baseline
- B Jobs displaced by automation by 2030 in the midpoint scenario
- C Jobs displaced by automation by 2030 in the rapid scenario
- D Jobs created by 2030 in the trendline scenario
- E Jobs created by 2030 in the step-up scenario
- F New occupations and unsized labor demand[1]
- G Change in labor force by 2030

Growth/decline of occupation types by 2030



1 Historical analysis suggests that we could expect 8-9% of 2030 labor supply will be in "new jobs" relative to today, which is additional to what we have estimated.

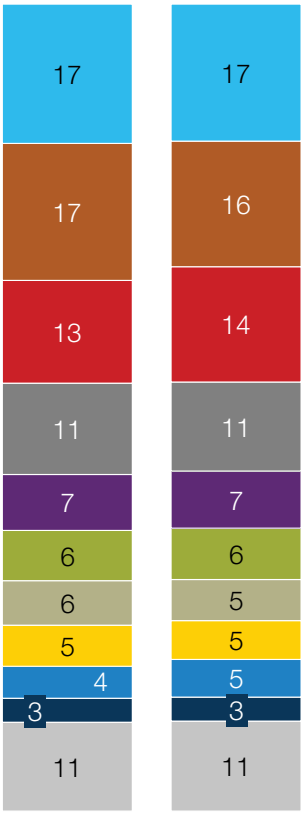
NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: McKinsey Global Institute analysis

Sector and occupation shifts

With automation and the labor demand catalysts, workers may need to switch occupations

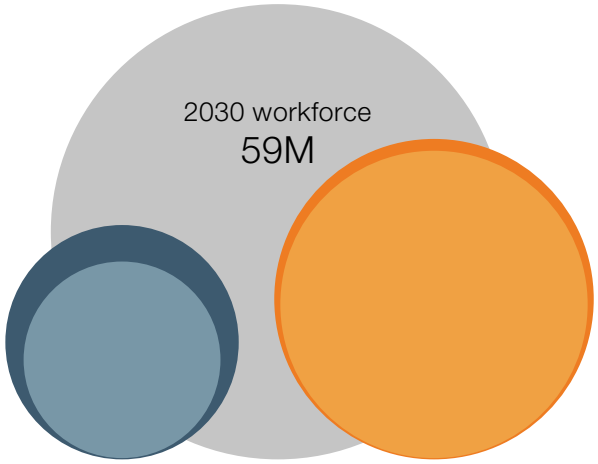
Sector share of labor force (%)[1]



Additions, net of automation (Million)

Retail and wholesale trade	-2
Manufacturing	-3
Health care	0
Government	-1
Accommodation and food services	-1
Construction	-1
Transportation	-1
Education	-1
Professional services	0
Information	0
Other	-1

Number of workers displaced by automation, and those needing to change occupational categories[2]

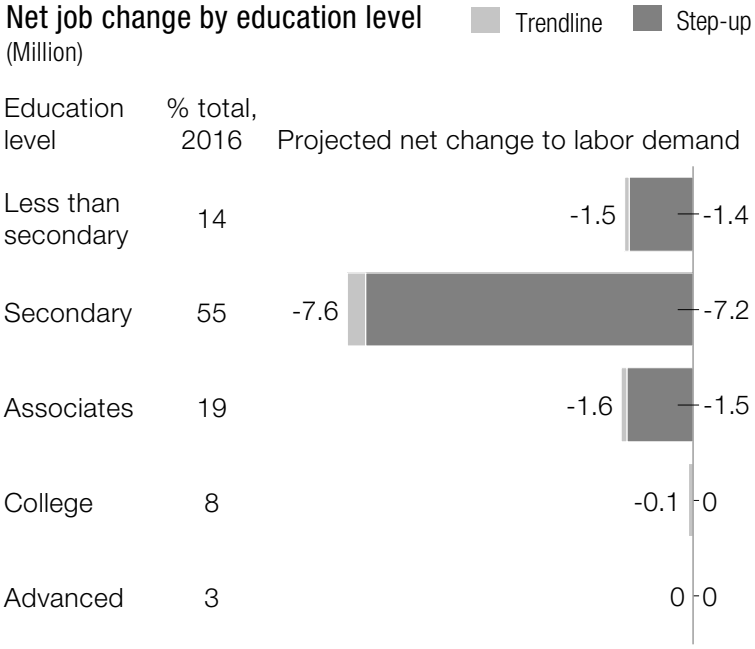


Midpoint automation	Rapid automation
16M displaced	30M displaced
10–11M changing occupations	27M changing occupations

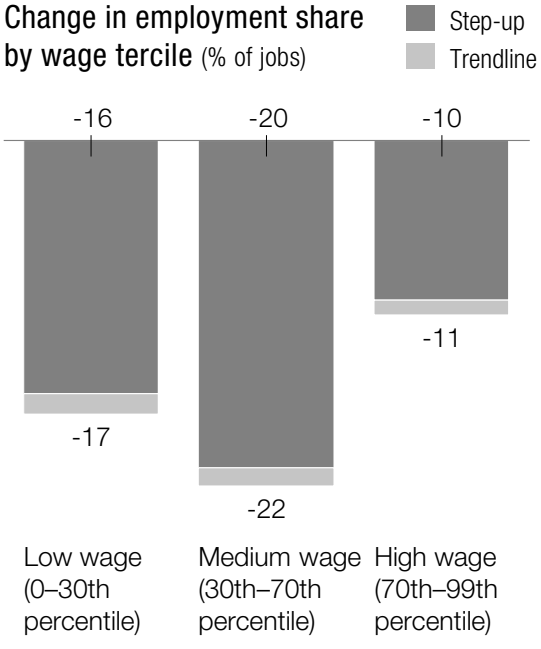
Up to 46% of the 2030 workforce may need to switch occupational groups

Job change by education and wage level, 2016–30[3] (midpoint automation)

Net job change by education level (Million)



Change in employment share by wage tercile (% of jobs)



1 Step-up scenario, midpoint automation, not all sectors modeled in labor demand catalysts (e.g., government).
2 "Transition" = switch occupation groups or gain new skills. Numbers given are trendline – step-up scenario.
3 Educational analysis based on current educational requirements. Employment analysis based on current wages.
NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.
SOURCE: McKinsey Global Institute analysis

Mexico

Mexico has a young population and a growing workforce. Mid- to low-wage levels may slow automation adoption, while comparatively low GDP growth may temper growth in labor demand. The step-up scenario will create enough labor demand to offset the effects of both automation and demographics.

Economics and demographic context

Demographics

6% over 65 years of age in today's population, and growing to 10% by 2030

Economic development

1.3% GDP per capita growth, annualized 2016–30

Wages

$9,000
average annual wage

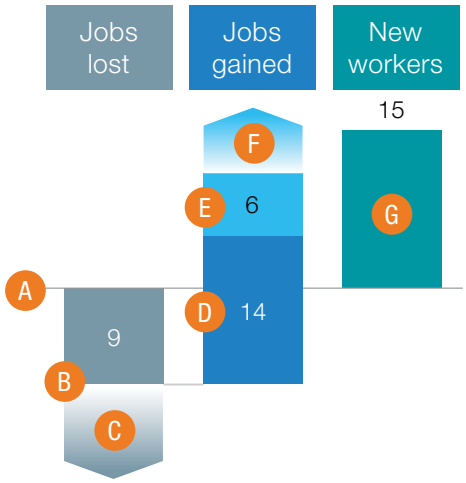
Automation potential

13% of current work activity hours automated by 2030
in the midpoint scenario, and up to 26% in the rapid scenario

Jobs lost, jobs gained

Net change in jobs by 2030 (Million)

Enough jobs are created in the step-up scenario to offset automation and the growth in labor force, given innovation in new work activities



- A 2016 baseline
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- C Jobs displaced by automation by 2030 in the rapid scenario
- D Jobs created by 2030 in the trendline scenario
- E Jobs created by 2030 in the step-up scenario
- F New occupations and unsized labor demand[1]
- G Change in labor force by 2030

Growth/decline of occupation types by 2030

Occupation type *Examples*	Net change in jobs (midpoint automation, step-up scenario)[2] Million	% of jobs 2016	 2030
Customer interaction *Retail sales, bartenders*	2.7	35	34
Builders *Construction workers, electricians*	1.7	7	8
Other jobs, predictable environments *Machinists, cooks*	1.7	25	24
Care providers *Surgeons, nurses*	1.6	4	5
Other jobs, unpredictable environments *Farmworkers, firefighters*	0.8	16	15
Office support *Payroll clerks, data entry*	0.7	6	6
Professionals *Lawyers, business specialists*	0.4	3	3
Managers and executives *CEOs, sales managers*	0.4	3	3
Educators *Teachers, librarians*	0.2	1	1
Technology professionals *Web developers, IT*	0.1	1	1
Creatives *Authors, designers*	0.1	0	0

1 Historical analysis suggests that we could expect 8-9% of 2030 labor supply will be in "new jobs" relative to today, which is additional to what we have estimated.

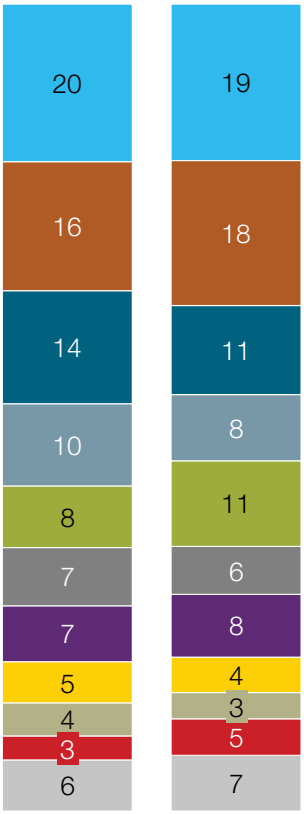
NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: McKinsey Global Institute analysis

Sector and occupation shifts

With automation and the labor demand catalysts, workers may need to switch occupations

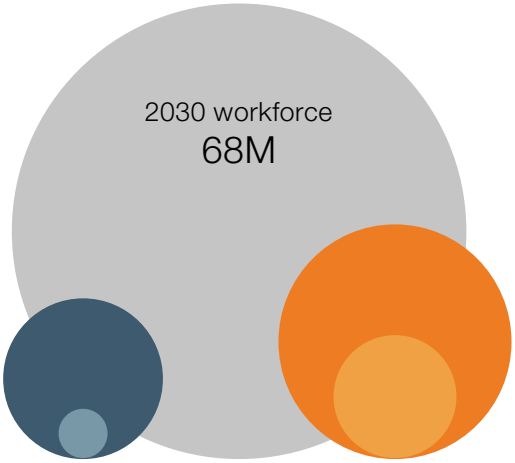
Sector share of labor force (%)[1]



Additions, net of automation (Million)

Retail and wholesale trade	+2
Manufacturing	+3
Agriculture	-1
Other services	0
Construction	+3
Government	0
Accommodation and food services	+1
Education	0
Transportation	0
Health care	+1
Other	+1

Number of workers displaced by automation, and those needing to change occupational categories[2]

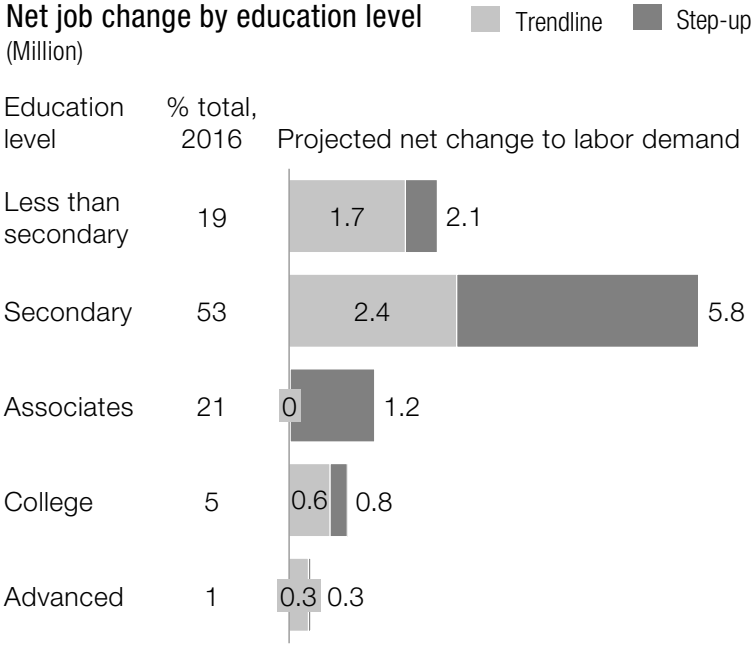


Midpoint automation	Rapid automation
9M displaced	18M displaced
1M changing occupations	5M–7M changing occupations

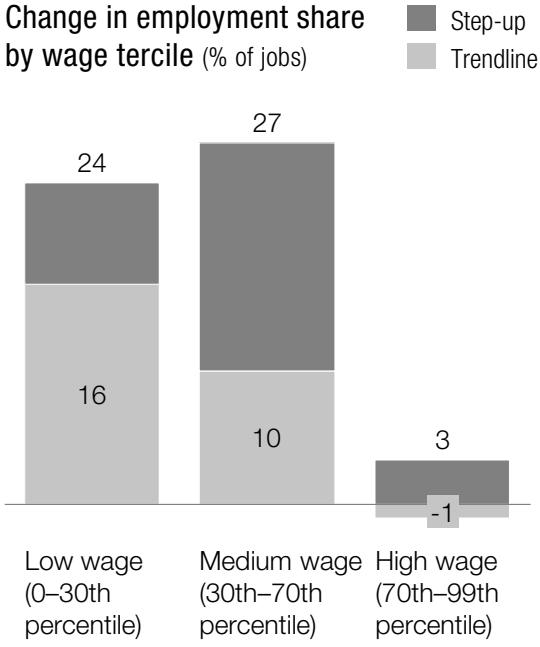
Up to 10% of the 2030 workforce may need to switch occupational groups

Job change by education and wage level, 2016–30[3] (midpoint automation)

Net job change by education level (Million)



Change in employment share by wage tercile (% of jobs)



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2 "Transition" = switch occupation groups or gain new skills. Numbers given are trendline – step-up scenario.
3 Educational analysis based on current educational requirements. Employment analysis based on current wages.
NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.
SOURCE: McKinsey Global Institute analysis

United States

Automation adoption will likely be significant in the United States, even as steady projected GDP per capita growth drives new labor demand. While labor demand will enable employment of displaced workers in the step-up scenario, up to one-third of the workforce may need to change occupational categories.

Economics and demographic context

Demographics

14% over 65 years of age in today's population, and growing to 21% by 2030

Economic development

1.3% GDP per capita growth, annualized 2016–30

Wages

$44,700
average annual wage

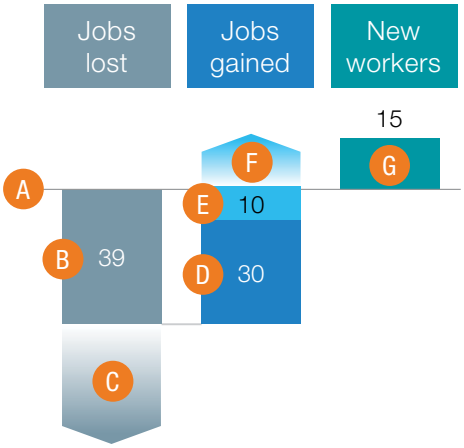
Automation potential

23% of current work activity hours automated by 2030
in the midpoint scenario, and up to 44% in the rapid scenario

Jobs lost, jobs gained

Net change in jobs by 2030 (Million)

Enough jobs are created in the step-up scenario (along with growth in new occupations) to offset both automation and the growth in labor force



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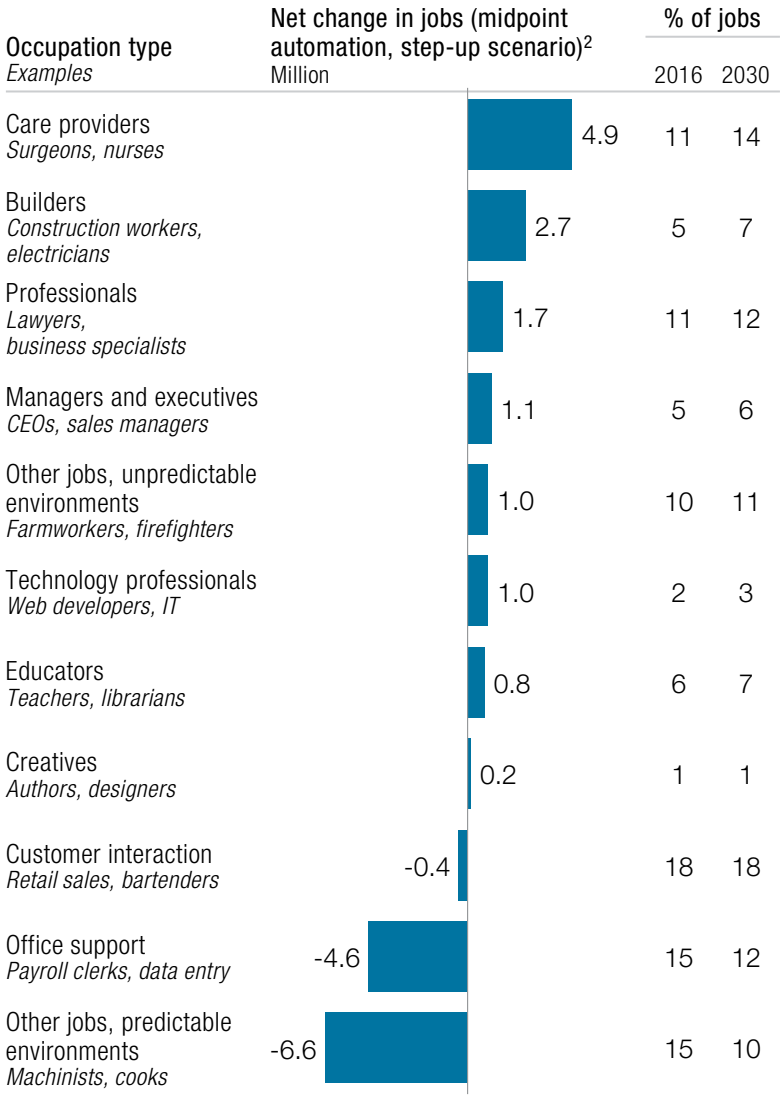
Growth/decline of occupation types by 2030



1 Historical analysis suggests that we could expect 8-9% of 2030 labor supply will be in "new jobs" relative to today, which is additional to what we have estimated.

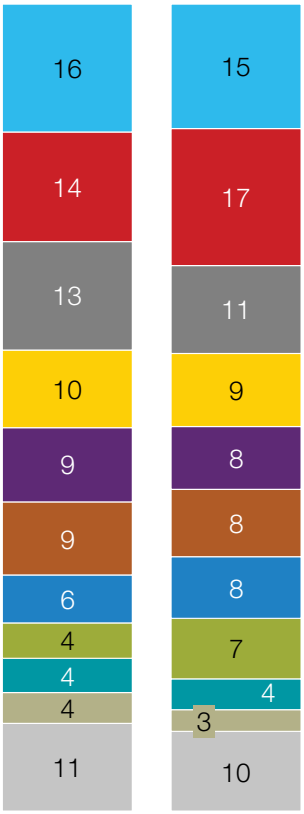
NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.

SOURCE: McKinsey Global Institute analysis

Sector and occupation shifts

With automation and the labor demand catalysts, workers may need to switch occupations

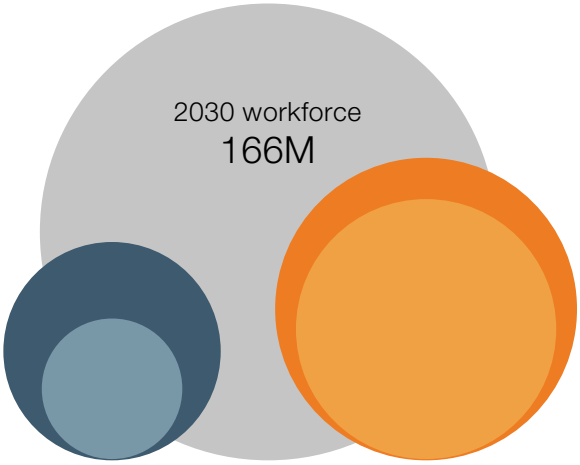
Sector share of labor force (%)[1]



Additions, net of automation (Million)

Retail and wholesale trade	0
Health care	+5
Government	-4
Education	-1
Accommodation and food services	-2
Manufacturing	-1
Professional services	+2
Construction	+5
Finance	0
Transportation	-2
Other	-1

Number of workers displaced by automation, and those needing to change occupational categories[2]

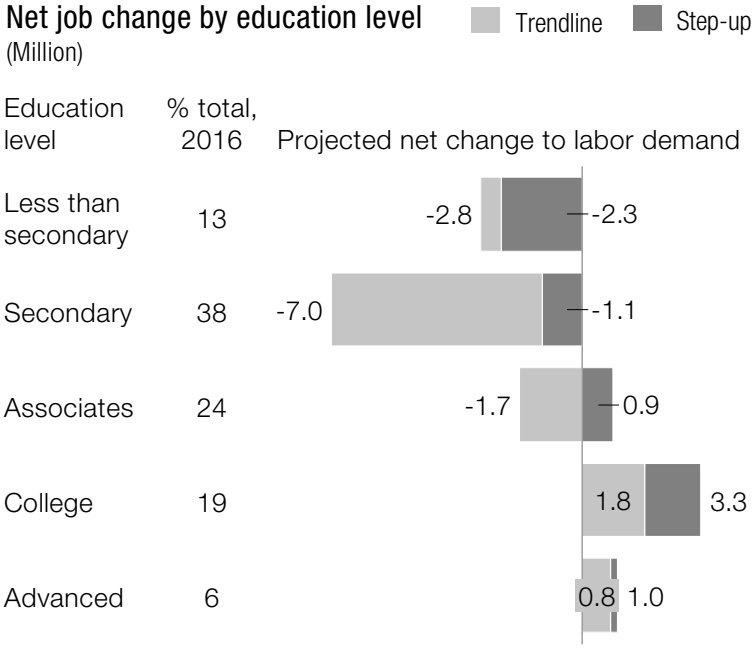


Midpoint automation	Rapid automation
39M displaced	73M displaced
13M–16M changing occupations	48M–54M changing occupations

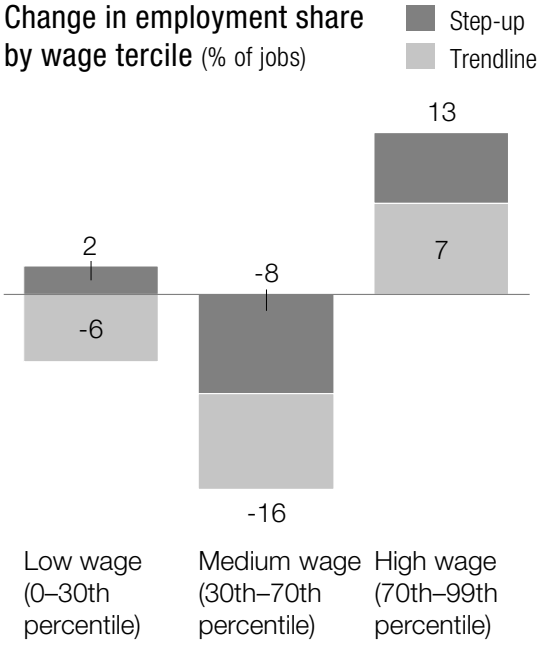
Up to 33% of the 2030 workforce may need to switch occupational groups

Job change by education and wage level, 2016–30[3] (midpoint automation)

Net job change by education level (Million)



Change in employment share by wage tercile (% of jobs)



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3 Educational analysis based on current educational requirements. Employment analysis based on current wages.
NOTE: Some occupational data projected into 2016 baseline from latest available 2014 data.
SOURCE: McKinsey Global Institute analysis

Office workers in the state of Washington, United States
© Thomas Barwick/ DigitalVision/Getty Images

5. MANAGING THE WORKFORCE TRANSITIONS

Brace yourself. All countries will face large-scale workforce transitions over the next 15 years as automation displaces some workers and labor demand shifts. Enabling and smoothing these transitions will be a significant challenge for policy makers and business leaders. Some policy choices could substantially improve the employment outcomes, including speeding reemployment. Indeed, it may take a Marshall Plan-scale initiative of sustained investment by the public and private sectors in new training models and workforce transition programs to address all the social, political, and economic issues that automation will raise.

In this chapter, we discuss four priorities that could make a critical difference: maintaining robust economic growth to support job creation; scaling up workforce retraining and skill development programs, particularly for midcareer workers; improving labor market dynamism; and providing income and transition support to displaced workers. We explore some of the choices that could be considered and cite examples of successful interventions. These ideas should not be taken as exhaustive or prescriptive, but rather as prompts to spur discussion and new ideas. Specific choices will vary based on country circumstances and societal choices.

MAINTAINING ROBUST ECONOMIC GROWTH AND INNOVATION TO SUPPORT JOB CREATION

The starting point is an economic one: sustaining robust aggregate demand growth is essential for enabling employment growth. Economies that are not expanding do not create new jobs. Indeed, the experience of the past decade has underscored the lingering negative employment effects of insufficient demand.

Appropriate fiscal and monetary policies can be deployed to ensure that demand growth is vibrant, and it goes beyond the scope of this report to catalog the appropriate macroeconomic policies. Nonetheless, the importance of sustaining demand growth cannot be overemphasized. Much has also been written about potential ways to encourage innovation and entrepreneurship, from investments in research and development and human capital, to investment capital, and lowered barriers to entry for innovative businesses.[104] Supporting innovation and technological diffusion is critical, including the adoption of automation technologies themselves, as these advances are the fundamental source of long-run productivity, growth, and prosperity, as well as the creation of new business models, occupations, and work activities. To do so will require an effective and balanced system for encouraging the development and deployment of intellectual property, a high-skill scientific and engineering workforce, and public or private funding for basic research and its commercialization. New business creation, start-up communities, and dynamic firm entry and exit are also essential.[105] For small cities that lack a diversified economy and where the principal employer leaves, more holistic economic revival plans are needed.[106]

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[104] See, for instance, Brad Feld, *Startup communities: Building an entrepreneurial ecosystem in your city*, Wiley, October 2012 and Enrico Moretti, *The new geography of jobs*, Mariner Books, March 2013.

[105] See *Making it in America*, McKinsey Global Institute, June 2017.

[106] See Amy Goldstein, *Janesville: An American story*, Simon & Schuster, 2017.

Actions can be taken not only at the national level, but also locally. MGI studies of cities around the world, along with a growing body of academic research, illustrate the vast differences in economic growth and prosperity that arise among cities and regions of the same country.[107] The last 20 years of globalization and technological change have resulted in many communities in the United States and Europe suffering large-scale job losses—but some of these communities have also shown that reviving growth through knowledge-based economies is possible. A common pattern emerges: harnessing intellectual capital, often found in universities, with private sector R&D and local governments willing to ensure workforce training to meet the new demand.[108]

Many policymakers, in both advanced and developing countries such as India, worry about "jobless growth."[109] Since the 2008 global financial crisis, it has become clear that not all sources of GDP growth have an equal impact on employment creation. Growth in industries that are heavily capital-intensive or those that are highly automated will not have the same impact on job creation. To support broad-based job creation, some countries may provide incentives to labor-intensive service sectors, such as health care, education, and construction. Targeted initiatives may also be used. Catalyzing public and private investment for infrastructure, including the housing and commercial buildings needed in urbanizing countries in the developing world, not only supports long-term economic growth but also has the potential to create large-scale employment in the near-term. Supporting measures to shift energy to renewable sources, manage and mitigate climate change, and boost energy efficiency through increased digitization of the sector likewise have global economic benefits while boosting near-term employment. The step-up scenario we outline in Chapter 3 reflects the potential impact of these types of "no-regret" initiatives; we estimate that roughly 150 million to 300 million jobs could be created incrementally on top of the trendline scenario jobs as a result. Importantly, these initiatives create many middle-skill jobs, such as those for electricians, carpenters, crane operators, and other trades.

In prior research, we examined the critical role of migration and gender parity, both of which amount to low-cost ways to boost aggregate demand in the short- and medium-term. For example, as much as 70 percent of population growth in urban areas going forward could come from migration—with key challenges on how migrants can be integrated effectively.[110]

SCALING UP JOB RETRAINING AND WORKFORCE SKILL DEVELOPMENT

Providing job retraining and enabling individuals to learn marketable new skills throughout their lifetimes will be a central challenge for some countries over the next decade and beyond. As we have shown in this report, hundreds of millions of people will likely need to find new jobs as automation advances, and even more will need to learn new skills, including how to work seamlessly with machines.

In recent years, some countries have experienced significant challenges in trying to create the conditions in which workers displaced by globalization and technology quickly find new high-quality employment. The result for many individuals has been a series of lower-wage jobs with limited opportunities for advancement and lower rates of labor market

[107] *Urban world: Mapping the economic power of cities*, McKinsey Global Institute, March 2011; Ibid. Enrico Moretti, *The new geography of jobs*, March 2013.

[108] Antoine van Agtmael and Fred Bakker, *The smartest places on Earth: Why rustbelts are the emerging hotspots of global innovation*, PublicAffairs, March 2016.

[109] *Asian experience on growth, employment and poverty: An overview with special reference to the findings of some recent case studies*, UNDP and International Labour Organization, January 2007.

[110] Ibid. *The power of parity*, McKinsey Global Institute, September 2015, and *People on the move: Global migration's impact and opportunity*, McKinsey Global Institute, December 2016.

participation.[111] The social consequences can be dire.[112] The challenge for the next decades will be to create effective workforce retraining programs at scale. This could require actions by policy makers, business leaders, and educators, as well as individuals.

History offers examples of large-scale programs to improve the skills of workers

At a time when millions of individuals will need new skills, public funding for job training programs is falling in many countries (Exhibit 27).[113] Between 1993 and 2015, spending on workforce training programs as a percent of GDP fell from 0.08 percent to 0.03 percent in the United States, while Japanese spending dropped from 0.03 percent to 0.01 percent. In Germany—still one of the larger spenders—outlays for training fell from 0.57 percent of GDP to 0.2 percent.

Nonetheless, we can find examples of societies, past and present, which have chosen to invest in education and workforce training, with impressive results. The United States provides examples of two at-scale investments in the past century: the US High School Movement (1910 to 1940), which made attending secondary school the norm for all children, and the 1944 GI Bill, which enabled millions of returning war veterans to obtain a tertiary education (see Box 6, "The US High School Movement and the GI Bill dramatically raised educational attainment of American workers"). Academic researchers have found that the sizable human capital increases enabled by these programs account for a measurable share of the rise in incomes over those decades, creating a large and increasingly affluent American middle class.[114]

120K
Number of workers in Singapore who have used a government initiative to upgrade skills

More recently, Singapore implemented an innovative form of support aimed at upgrading skills as part of its efforts to promote growth and competitiveness in 23 industries.[115] Through the "SkillsFuture Initiative," introduced by the Ministry of Education in January 2016, the government provides all Singaporeans aged 25 and above credit of about $400, to pay for approved work-skills related courses. More than 18,000 such courses are available, and as of December 2016, more than 120,000 people—some 4 percent of the resident population aged 25 and above—had used the initiative to take courses, more than 60 percent of them over 40.[116]

Businesses can play a significant role in training and retraining workers

Companies also have a significant role to play in training and retraining workers. This goes beyond a purely social role or sense of civic responsibility: business leaders will be on the front lines of automation and will have the earliest and most detailed knowledge about what types of skills they will need as they move to adopt the technologies. In the United States, some companies are working directly with education providers to give employees an opportunity to raise their educational and skill levels (see Box 7, "Some US companies are working with educational providers, even as spending on corporate training declines").

[111] See, for instance, David H. Autor, David Dorn, and Gordon H. Hanson, "The China shock: Learning from labor-market adjustment to large changes in trade," *Annual Review of Economics*, volume 8, October 2016.

[112] In the United States, for example, some studies show declining life expectancy for white US citizens under age 50, reflecting a surge in death from suicide, drug addiction, and alcoholism. Anne Case and Angus Deaton, "Rising morbidity and mortality in midlife among white non-Hispanic Americans in the 21st century," *Proceedings of the National Academy of Sciences of the United States of America*, volume 112, number 49, December 2015.

[113] *Public spending on labor markets*, OECD Data, 2017.

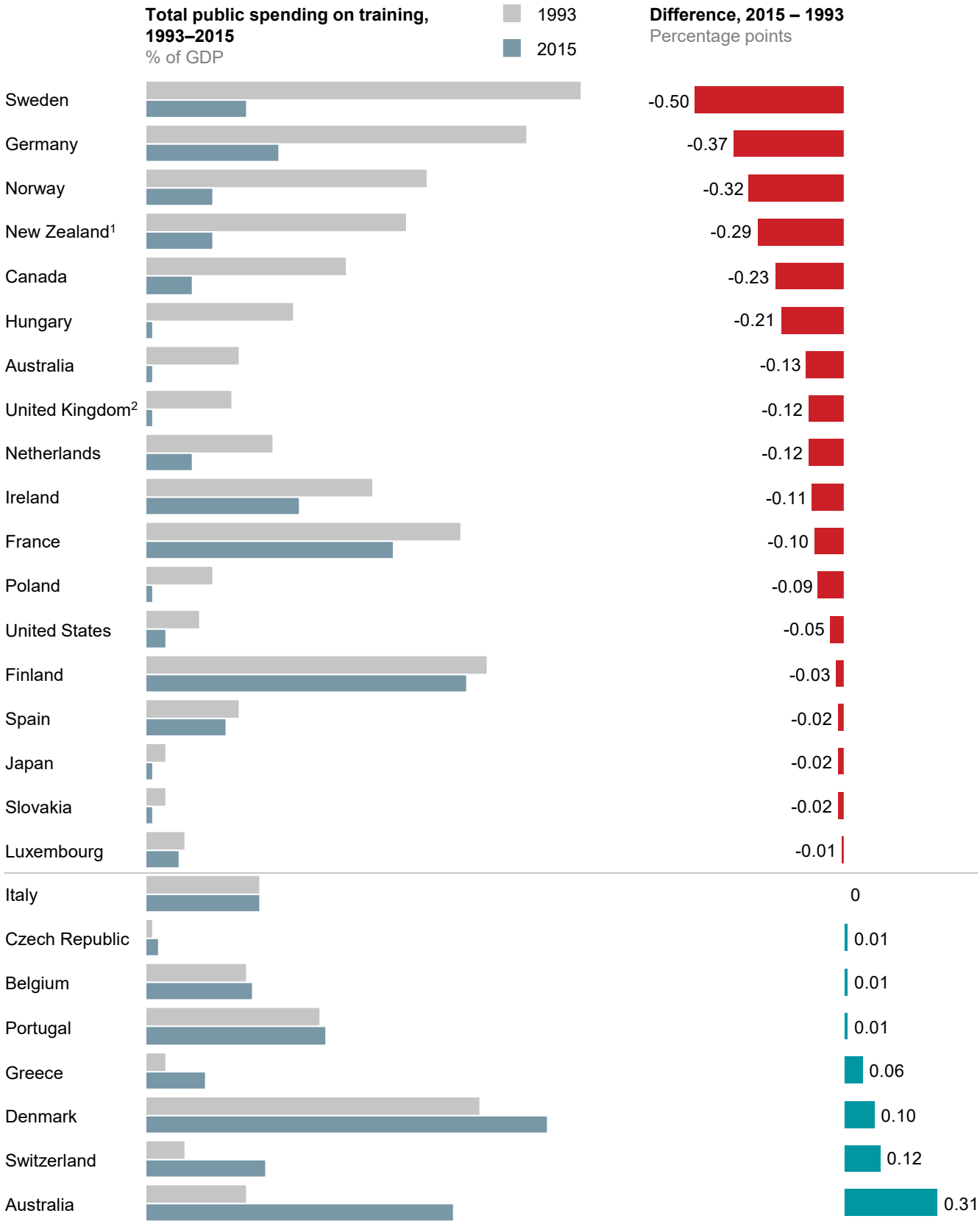
[114] Suzanne Mettler, *Soldiers to citizens: The GI Bill and the making of the greatest generation*, Oxford University Press, 2005.

[115] The overall program is known as Industry Transformation Maps, and skills upgrades are an integral part of it. See www.skillsfuture.sg.

[116] *Steady progress in implementation of SkillsFuture credit*, SkillsFuture factsheet, January 8, 2017.

Exhibit 27

Most OECD countries have been spending less on worker training over the past 20+ years



1 2014 data used for New Zealand.
2 2011 data used for United Kingdom.
NOTE: Countries where 1993 data was not available omitted Not to scale.

SOURCE: OECD; McKinsey Global Institute analysis

Box 6. The US High School Movement and the GI Bill dramatically raised educational attainment of American workers

The US High School Movement (1910 to 1940) propelled a sharp increase in high school enrollment and graduation rates, making a high school qualification the norm.[1]

In 1910, most students left education after primary school to work in agriculture or other low-skill jobs. Those who attended high school did so primarily to gain entrance to college. However, the economy had begun producing large numbers of jobs in cities that demanded a formal education beyond primary school. This demand led to a grassroots movement: more high schools were built and the curriculum shifted from teaching skills "for college" to skills "for life." Vocational (including commercial), technical or manual, and industrial courses were rapidly incorporated into most high school curricula.

Secondary school enrollment increased spectacularly, from 18 percent in 1910 to 73 percent in 1940. Graduation rates for 17-year-olds rose from 9 percent to 51 percent in the same period (Exhibit 28).

Higher educational attainment had an impact on incomes. On an aggregate level, national incomes per worker grew annually at a 1.48 percent average from 1929 to 1982. One study attributes 28 percent of the economic growth to human capital accumulation and technological progress, with changes at the secondary school level being quantitatively the most significant driver to the increased educational stock of Americans in the first three-quarters of the 20th century.[2]

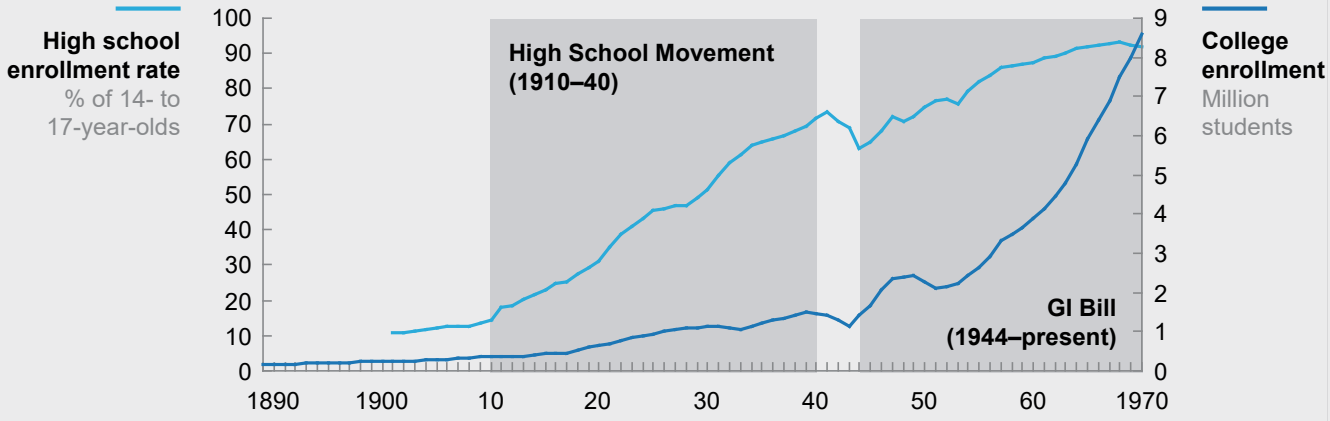
The GI Bill of 1944, created to help integrate World War II veterans back into civilian life, was instrumental in making a college education mainstream.[3] Studies estimate that 1.4 million people-years of undergraduate training had been lost because of the war.[4] The bill provided all veterans dedicated payments of tuition and living expenses to attend high school, college, or vocational or technical school. By 1956, just under eight million veterans had used the GI Bill educational benefits, with 2.2 million attending colleges or universities and an additional 5.6 million engaging in some kind of training program.[5] In all, just over half of all veterans tapped the education benefits in some form, greatly exceeding the government's projections.[6] Veterans accounted for as many as 49 percent of all enrolled students at colleges and universities—and created demand for growth of a world-class university system.[7]

The GI Bill also changed perceptions about college attendance, making it accessible to the average person and not simply reserved for an elite.

Exhibit 28

The High School Movement and GI Bill significantly raised education and skill levels in the United States

Evolution of high school and college enrollment, 1890–1970



SOURCE: Claudia Goldin, "America's graduation from high school: The evolution and spread of secondary schooling in the twentieth century," *Journal of Economic History*, volume 58, number 2, June 1998; National Center for Education Statistics; McKinsey Global Institute analysis

1 Ibid. Claudia Goldin, "America's graduation from high school," June 1998.
2 Ibid.
3 Michael J. Bennett, *When dreams came true: The GI Bill and the making of modern America*, Brassey's Publishing Co., 1996.
4 Roger M. Shaw, "The GI challenge to the colleges," *Journal of Higher Education*, volume 18, 1947.
5 Ibid. Milton Greenberg, "How the GI Bill Changed Higher Education," June 18, 2004.
6 Keith W. Olson, "The G. I. Bill and Higher Education: Success and Surprise," *American Quarterly*, volume 25, number 5, December 1973.
7 Ibid. Milton Greenberg, "How the GI Bill Changed Higher Education," June 18, 2004.

Box 7. Some US companies are working with educational providers, even as spending on corporate training declines

Spending on corporate training in the United States has been declining for decades, along with public spending on workforce training (Exhibit 29).[1]

Against that background, some employers have begun offering educational assistance and programs to their workforces to fill current gaps in skills needed or in response to a looming number of retirees. For example, AT&T has partnered with Georgia Tech to provide opportunities for all employees to enroll in the university's online computer science program, which AT&T helped set up. AT&T's move was aimed at bridging a skills gap: internal projections suggested that 95 percent of the 135,000 employees in its technology and services unit would need training in STEM subjects—science, technology, engineering, and mathematics—whereas only 50 percent had such training in 2013.[2] AT&T offers scholarships to all employees to attend classes, pays tuition, and enables employees who did not go to a brick-and-mortar university to improve their technical skills. In 2014, about 18 percent of the 1,268 students enrolled in Georgia Tech's computer science master's program were AT&T employees.[3]

Walmart, the world's largest private-sector employer with a global workforce of nearly 2.5 million, is conducting training and retraining of its US employees in-house, through its Walmart Academy. This is one of the largest employer training programs in the United States. The company expects to train more than 225,000 associates by the end of 2017, using both experiential, on-the-floor training and traditional classroom instruction.[4]

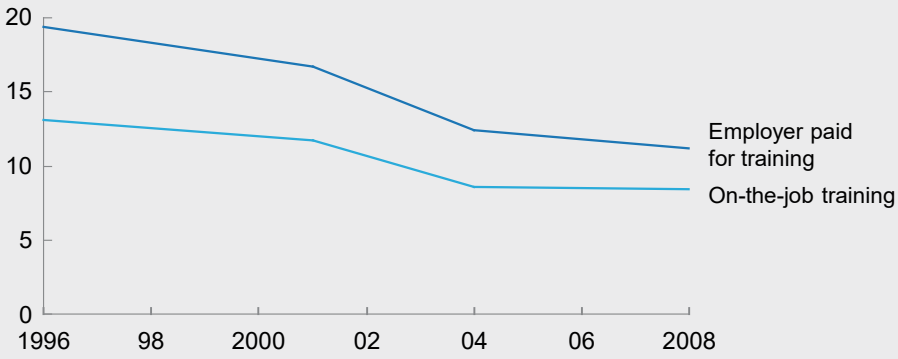
Other companies offer broader educational assistance for employees to attain any degree, whether it is linked to the company or not. For instance, Starbucks has entered a partnership with Arizona State University that provides an opportunity for all eligible employees to earn their bachelor's degree with full tuition coverage all the way to graduation through ASU's online degree program.[5] Amazon, through its Career Choice program, reimburses 95 percent of tuition, fees, and materials of its hourly associates with as little as one continuous year of tenure for a wide array of accredited degree programs.[6]

Some employers are working together with educators to train young workers for jobs in high-growth areas including technology, health care, and customer service.[7]

Exhibit 29

US workers receiving employer-sponsored or on-the-job training

Share of US workers receiving employer-sponsored or on-the-job training, 1996–2008
Fraction of workers ages 18–65 receiving training of any duration in the last year
%



SOURCE: 2015 Economic Report of the President; US Council of Economic Advisors; Census Bureau; Survey of Income and Program Participation (Employment and Training Topical Module); CEA calculations; McKinsey Global Institute analysis

1 This trend is not true in Europe, for example. See *Economic Report of the President* prepared by the US Council of Economic Advisers, February 2015, and Jean-François Mignot, "Continuing training for employees in Europe: The differences between countries continue to narrow" Céreq Training & Employment, July-August 2013.

2 Aaron Pressman, "Can AT&T retrain 100,000 people?" *Fortune*, March 13, 2017.

3 Natalie Kitroeff, "Why AT&T is investing in virtual school," *Bloomberg*, October 24, 2014.

4 Jacqui Canney, "The future of work is already here," LinkedIn, May 2, 2017; Michael Corkery, "At Walmart academy, training better managers. But with a better future?" *The New York Times*, August 8, 2017; Diane Stafford, "Inside Wal-Mart's new training sessions: Trying to adapt to retail landscape changes," *Chicago Tribune*, May 16, 2017.

5 "Starbucks offers full tuition reimbursement for employees to complete a bachelor's degree," Starbucks Newsroom, June 15, 2014, https://news.starbucks.com/news/starbucks-offers-full-tuition-reimbursement-for-employees-to-complete-a-bac

6 "Career choice," Amazon, https://www.amazon.com/p/feature/fsp92a2bhozr3wj

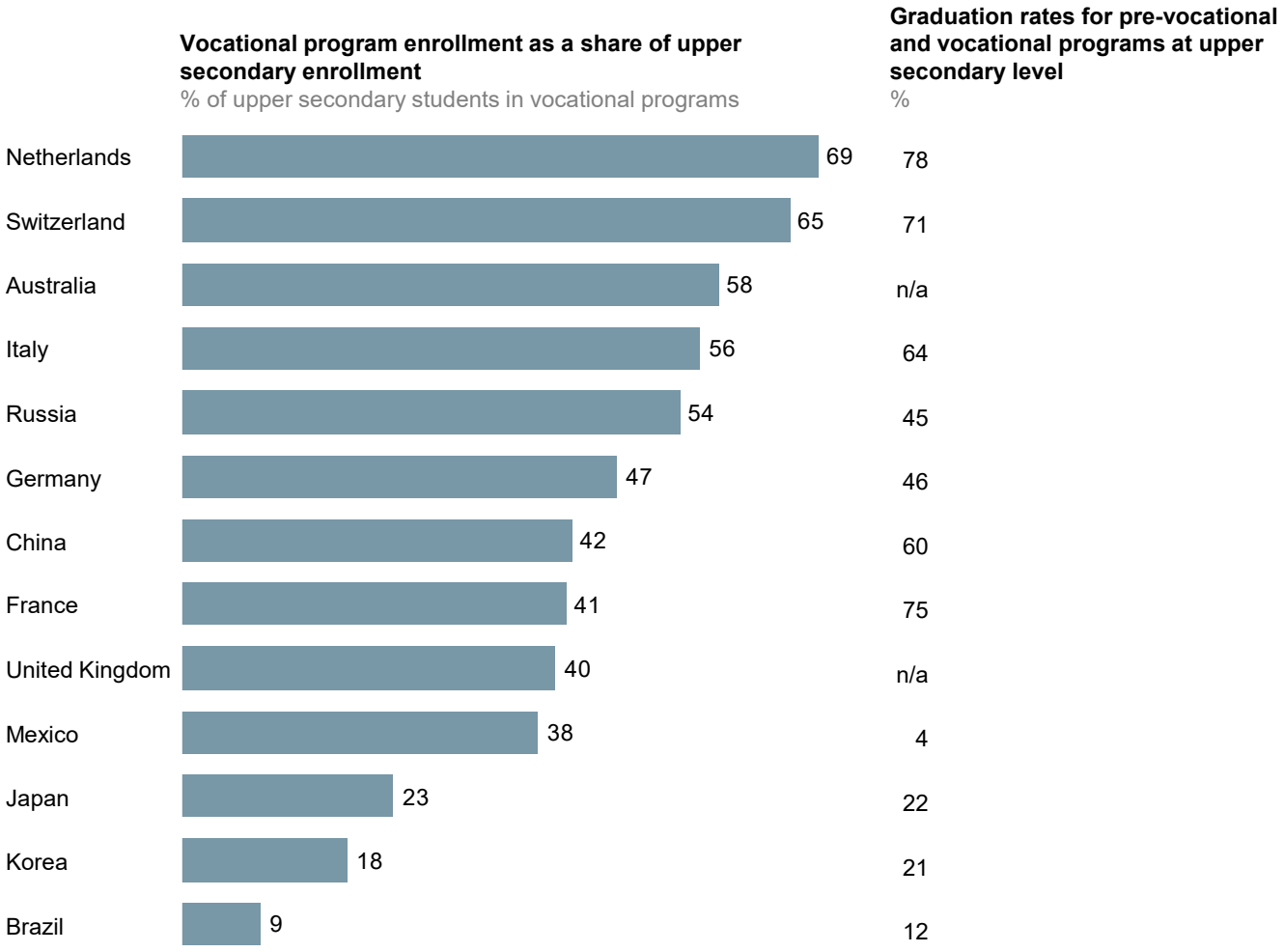
7 More than 10,000 youths have graduated globally from one such program, "Generation," founded by the McKinsey Social Initiative, a non-profit organization founded by McKinsey & Company, and supported by local and global funders including Walmart, USAID, and the European Commission. See Rana Foroohar, "US workforce: paying young Americans to learn the right skills," *Financial Times*, June 15, 2017.

Traditionally, educational degrees—especially in the fields of science, technology, engineering, and mathematics (STEM)—have acted as a signal of talent for job hiring. Lacking other markers of skills, many employees focused on whether candidates have multi-year, expensive degrees. As the workplace evolves, however, more granular and varied definitions of skills are emerging as critically important markers, more so even than a college education in some cases. This focus on an individual's skills rather than educational credentials is gaining momentum with companies, state governments, and nonprofit organizations. Markle Foundation, for example, has begun an initiative in Colorado to foster skills-oriented hiring, training, and education. Among companies supporting it, Microsoft has announced a grant of more than $25 million to support the program, known as Skillful.[117]

One intensive approach to corporate training programs merges on-the-job training with formal education through apprenticeships. These programs exist in many countries, although participation and graduation rates vary (Exhibit 30).

Exhibit 30

Vocational enrollment rates vary greatly by country, though the highest rates are found in developed countries


Vocational program enrollment as a share of upper secondary enrollment
% of upper secondary students in vocational programs
Graduation rates for pre-vocational and vocational programs at upper secondary level
%
Netherlands 69 78
Switzerland 65 71
Australia 58 n/a
Italy 56 64
Russia 54 45
Germany 47 46
China 42 60
France 41 75
United Kingdom 40 n/a
Mexico 38 4
Japan 23 22
Korea 18 21
Brazil 9 12

NOTE: Exact US vocational enrollment rates are not available from OECD; per the US National Center for Educational Statistics, ~1 million students are in vocational programs, with ~15 million total high school students. Data used is latest available, for 2012, except for Australia (2011).

SOURCE: OECD; McKinsey Global Institute analysis

[117] Steve Lohr, "A new kind of tech job emphasizes skills, not a college degree," *New York Times*, June 28, 2017.

Apprenticeships primarily benefit youth newly entering the workforce. Germany's "dual-system" apprenticeship program combining work- and school-based learning is the best known, and prepares students for a successful transition to full-time employment. Beginning in secondary school, students choose a vocational or a college-preparation track. Traditionally, this allocation was done through student test scores, but today there is more flexibility. Vocational students spend part of their time attending high school, learning the basic curriculum, and part of their time working and earning at an employer. The system offers qualifications in a broad spectrum of professions and adapts to the changing needs of the labor market.

A major strength of the dual system is the high degree of engagement and ownership on the part of employers, although a web of checks and balances at the national and local levels ensures that the short-term needs of employers do not distort broader educational and economic goals.[118] The system has produced impressive results: about one-third of German students are educated in the apprenticeship system, which is a widely respected career path.

Like Germany, Switzerland also has a robust apprenticeship pipeline—indeed, nearly 70 percent of Swiss high-school students choose vocational training. In this track, students rotate between school and workplace settings, and receive a salary throughout their training.[119] Some studies show that students in Switzerland who opt into vocational training over general education on average attain higher lifetime earnings.[120]

Germany's apprenticeship system is being emulated by other countries. For instance, German auto manufacturers in the United States now offer apprenticeships (although the program remains small). South Korea has adopted the apprenticeship model at scale (see Box 8, "South Korea's Meister schools apprenticeship system").

[118] *Vocational education and training in Germany: Strengths, challenges, and recommendations*, OECD, 2010.

[119] *Gold standard: The Swiss vocational education and training system*, Center on International Education Benchmarking, March 2015.

[120] Eric A. Hanushek, Ludger Woessmann, and Lei Zhang, *General education, vocational education, and labor-market outcomes over the life-cycle*, CESifo working paper, number. 3614, October 2011.

Box 8. South Korea's Meister schools apprenticeship system

South Korea has one of the highest university enrollment rates in the world, but unemployment rates for graduates have been high, even as small- and medium-sized businesses cannot fill openings for manual and other jobs. The government studied the German and Swiss apprenticeship systems and transformed a subset of existing vocational schools into "Meister" ones. (*Meister* is German for a skilled craftsman.) Students graduate with the equivalent of two years' work and/or community college experience. To provide incentives, the Korean government pays the students' tuition, room, and board.

The program is still relatively young, but already bearing fruit: Meister schools have produced significantly higher employment rates among their graduates, more than 90 percent, compared with less than 65 percent for college graduates. College enrollment rates have fallen in favor of vocational qualifications as a result.[1]

[1] Ministry of Education, South Korea.

Educators have a role to play in adjusting school curricula for the automation age

While automation will be a major challenge to workers already in jobs, it also will have implications for how future generations of workers are trained, involving adjustments to school curricula and education systems more broadly. Curricula will need to adapt to provide students with the skills necessary for a dynamic, technology- and increasingly service-oriented labor market, particularly in countries and industries where automation technologies are likely to be adopted most quickly. Several changes will be required.

First, demand will increase for workers to develop and deploy technology, or interpret and act on the data analytics that these technologies can produce, yet there may not be enough workers with the skills to meet this demand, for instance, for data scientists.[121] STEM subjects will be crucial for the workforce. Early education in subjects such as statistics, to help students understand an increasingly data-driven world, where experiments are a key source of insight, will be vital. Some countries including Estonia and the United Kingdom have introduced computer coding into primary and secondary education. Coding classes in these countries start as early as age five or seven, with an introduction to necessary fundamental concepts (such as gaining an understanding of algorithms) and coding skills such as logic and the creation and debugging of simple computer programs.[122] However, a strong liberal arts education to go alongside the high tech workplace skills could also be required for the "new collar" jobs of the future.[123]

Our analysis has shown that an increasing percentage of activities that workers will do in the future will be in categories such as managing and leading other people and interacting with others, which require skills such as social and emotional sensing and reasoning, and applying creativity and collaborative problem-solving. These skills are often not part of the formal curriculum in traditional school programs. Another finding from our research is that automation and other factors, including globalization, independent work, and companies crossing sector boundaries, will require all workers to change what they do over time. This puts a premium on a set of meta-skills, around agility, flexibility, grit, and learning how to learn. Teaching such qualities is a challenge for all educational systems.

39%
Percentage of employers who say that a skills shortage is a cause of entry-level vacancies

Third, educational institutions will need to adapt to the evolving demands of the labor market to ensure that critical job skills are being taught. Unless they become more responsive to labor market demands, educators risk creating an ever-larger disconnect between education and employment. This disconnect is already visible in some surveys. In a McKinsey survey in 2012, only 50 percent of youths said they believed their post-secondary studies improved their employment opportunities, and only 43 percent of employers reported being able to find enough skilled workers. Moreover, 39 percent of employers said a skills shortage was a leading reason for entry-level vacancies. However, a big majority of education providers (72 percent) said they believed new graduates were ready to work.[124]

[121] *The age of analytics: Competing in a data-driven world*, McKinsey Global Institute, December 2016.

[122] Parmy Olson, "Why Estonia has started teaching its first-graders to code," *Forbes*, September 6, 2012; Richard Wilson, "Computer programming will soon reach all Estonian schoolchildren," *Ubuntu Life*, May 4, 2014; *Computing programmes of study. Key stages 1 and 2*, UK Department of Education, September 2013. It is also important to note that the aims of introducing coding into early education are not to teach specific computer languages, which change constantly in their popularity, but rather computational thinking.

[123] George Anders, *You can do anything: The surprising power of a "useless" liberal arts education*, Little, Brown & Company, August 2017.

[124] *Education to employment: Designing a system that works*, McKinsey & Company, January 2013.

Several measures can reduce or correct disconnects among education providers, employers, and students. Providing actionable data is one. Students need to know that curricula will provide them with relevant knowledge and work skills, and be able to select the best courses and institutions to achieve their desired educational outcome. In one survey, less than 50 percent of students said they had a solid understanding of which disciplines lead to professions with good job openings and wage levels.[125]

Finally, the digital age itself has brought a multitude of possibilities for new ways of learning, both within the educational system and outside. Digital learning resources are more flexible in terms of their timing and content than traditional classroom training, and programs can adjust content for individual students to optimize their learning outcomes. For individuals, online degrees can be more advantageous from a cost perspective than degrees from traditional colleges and universities, particularly in the United States where tuition costs are rising faster than overall inflation. Some massive open online courses (MOOCs) are free and have helped expand access to educational content for those outside traditional educational institutions. At Coursera, for example, half of students are from developing countries, and about 60 to 70 percent of users are employed but preparing for better jobs, while 15 percent are unemployed. Most are between ages 22 and 45.[126] MOOCs present a promising channel for at-scale distribution of educational content at low cost and have potential to help ease future workforce transitions. However, their educational impact at scale remains to be seen.[127]

IMPROVING LABOR MARKET DYNAMISM

Workers in countries with more fluid labor markets find work more quickly and obtain jobs that are a better fit; this will blunt potential increases in unemployment as automation is adopted. For now, there are significant information asymmetries in the workforce, with poor job matching: companies struggle to find the people they need, and people cannot find the opportunities for which they are best qualified. Both policy changes and new digital tools can help address this challenge.

Labor market fluidity has been declining within advanced economies

In advanced economies, there is evidence that labor markets are becoming less dynamic, with fewer people switching jobs.[128] One striking example is the United States, which has experienced a decline in job reallocation rates since the early 1980s (Exhibit 31).[129] The root causes of this decline are not fully understood, but include an aging workforce that is less likely to change jobs, declining rates of new business formation, lower geographic mobility (see next section), and increasing regulations, licensing, and more intense training requirements that have made it harder to join some professions.[130] Removing overly burdensome occupational licensing and restrictions, ensuring that benefits are not lost in moving from one employer to another, and easing the process and financing for entrepreneurs to start new firms and for existing firms to innovate are all part of the solution.

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[125] Ibid.

[126] Coursera.

[127] For example, edX has reported that between 2012 and 2016, only 5.5 percent of enrollees completed certifications. Isaac Chuang and Andrew Dean Ho, *HarvardX and MITx: Four years of open online courses—fall 2012–summer 2016*, SSRN, December 23, 2016.

[128] See Steven J. Davis and John Haltiwanger, *Labor market fluidity and economic performance*, NBER working paper 20479, September 2014; Raven Molloy et al., *Understanding declining fluidity in the US labor market*, Brookings Papers on Economic Activity, spring 2016.

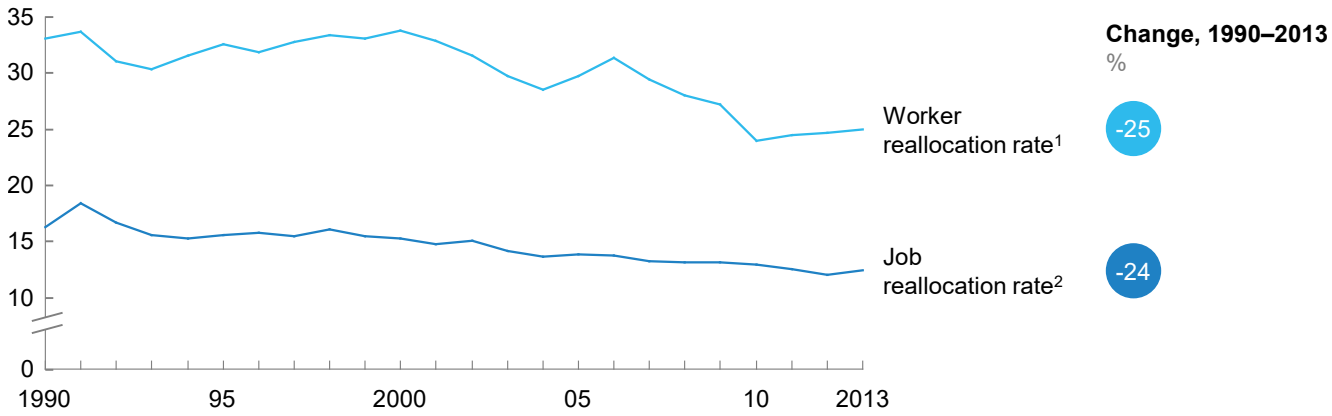
[129] Ibid. Steven J. Davis and John Haltiwanger, *Labor market fluidity*, September 2014.

[130] *Dynamism in retreat: Consequences for regions, markets and workers*, Economic Innovation Group, February 2017.

Exhibit 31

Measures of labor market dynamism have been declining in the United States

Quarterly rates of common measures of labor market dynamism for the United States, 1990–2013
% of total employment



1 Worker reallocation rate: sum of hires and separations, inclusive of retires and other separations, expressed as percentage of total employment.
2 Job reallocation rate: sum of job creation and destruction rates.

SOURCE: Steven J. Davis and John Haltiwanger, *Labour market fluidity and economic performance*, NBER working paper number 20479, September 2014; McKinsey Global Institute analysis

Improving geographic mobility can enhance labor market fluidity

While our analysis does not look at the intra-country geography of job loss and job growth, it is clear that increasing the geographic mobility of the workforce will aid the transition. Yet labor mobility has declined steadily in many advanced economies.[131] In the United States, geographic mobility has declined since the 1980s (both within and between states), reversing the increased mobility that was a characteristic of the US labor market earlier in the 20th century.[132] Whereas about 3 percent of workers relocated across state lines each year prior to 1990, that figure has steadily fallen to closer to 1.5 percent today, suggesting that geographic labor mobility halved within less than 30 years. In Europe, despite the ambition of creating free movement of people, mobility across borders is still complicated, especially for services, in which regulating the cross-border posting of workers remains subject to political disagreements and different labor market regulations. In the European Union, overall, about 17 million people, or 3 percent of the population, have taken advantage of the free movement possibilities to live in a different EU country, although the annual flow is one tenth of that, about 0.3 percent of the population.[133]

Improving geographic mobility may require regulatory change as well as incentives. One major obstacle to internal mobility is the cost and availability of housing. Academic literature has shown that residential mobility is positively correlated with worker reallocation rates and the efficiency of job matching.[134] Lack of information on job opportunities in other areas, family ties, and different job licensing requirements are also deterrents, as are legal hurdles such as land-use laws, different eligibility standards for public benefits, state and local tax regimes, and even basic property law rules.[135]

131 Developing countries are experiencing massive migration of workers from rural areas to urban areas as they urbanize and industrialize.

132 Raven Molloy, Christopher L. Smith, and Abigail Wozniak, *Declining migration within the US: The role of the labor market*, Federal Reserve Board, Finance and Economics Discussion Series, number 27, April 2014.

133 Mikkel Barslund and Matthias Busse, *Labour mobility in the EU: Addressing challenges and ensuring "fair mobility,"* CEPS special report number 139, July 2016.

134 *Economic policy reforms 2011: Going for growth*, OECD, April 2011.

135 David Schleicher, "Stuck! The law and economics of residential stagnation," *The Yale Law Journal*, volume 127, number 1, October 2017.

International mobility is a controversial topic in some political arenas, but the skill mismatches we have identified as a consequence of automation and new labor demand will not stop at national borders. Our research on global migration has found that the world's 247 million cross-border migrants contributed 9.4 percent of global GDP, or roughly $6.7 trillion worldwide in 2015—more than $3 trillion above their contribution had they remained in their home countries.[136] More than 90 percent of these cross-border migrants moved voluntarily, usually for economic reasons, while refugees and asylum seekers who tend to attract the most public attention make up the remainder.

Digital platforms can make labor markets more transparent and improve job matching

Digital platforms offer an efficient way to improve the information available to individuals about job opportunities, and to companies about job candidates. By improving information signals, job platforms such as LinkedIn, Indeed.com, and Monster.com can speed and improve the process of matching individuals to jobs, thereby fostering fluidity. These platforms allow individuals to post their entire resume and showcase their work, displaying a rich set of credentials and skills other than simply their educational record. But transparency cuts both ways: other platforms, such as Glassdoor.com, enable prospective employees to find out more about their potential employers, including salary information and anonymous reviews by current employees. MGI has estimated that up to 540 million individuals could potentially benefit from online talent platforms, with as many as 230 million shortening search times between jobs, reducing the duration of unemployment. Up to 60 million people could find work that more closely suits their skills or preferences, and an additional 50 million could shift from informal to formal employment.[137]

Companies can benefit from using digital technologies to transform recruiting, training, and managing talent as well. Companies that adopt these tools are discovering that better-informed decisions about human capital produce better business results. On average, our analysis finds that companies could see a 275 basis point increase in their profit margins.[138] In addition, talent platforms could improve signaling about the skills that are actually in demand. As this information shapes decisions about education and training, the supply of skills in the economy could adjust more quickly and accurately over time.

Creating more flexible work options may enhance reemployment of displaced workers

The workplace is changing, with the rise of more flexible forms of independent work, including independent contractors, freelancers, self-employed individuals, and people working in the "gig" or "sharing" economy. MGI finds that 20 to 30 percent of the working age population in Europe and the United States already earn income through independent work—and that 70 percent of those say they do so out of preference, not because they cannot find a traditional job. Moreover, the number of people choosing to work outside traditional jobs may rise.[139] Digital platforms such as Upwork, Freelancer.com, HourlyNerd, Uber, Lyft, TaskRabbit, eBay, and Airbnb offer vast new markets and lower the barriers to entry, thereby removing some of the risk for those who want to be their own boss.

Independent work may offer solutions as well as new challenges. Among the benefits, it can enable many people currently not employed to work in flexible ways that suit their needs. It is particularly attractive for care-givers, retirees, students, and others who need flexible schedules. For the unemployed, independent work may provide a critical bridge to keep earning income while seeking employment. But as independent work grows, questions

[136] Ibid. *People on the move*, McKinsey Global Institute, December 2016.
[137] Ibid. *A labor market that works*, McKinsey Global Institute, June 2015.
[138] Ibid.
[139] Ibid. *Independent work*, McKinsey Global Institute, October 2016

surrounding benefits, income security measures and other worker protections become more prominent and need to be addressed. Key policy recommendations of the United Kingdom's Taylor Review in July 2017, for instance, included recommendations to expand the definition of "worker," extend minimum wage standards, and ensure that benefits such as holiday and sick pay cover independent workers.[140]

PROVIDING TRANSITION AND INCOME SUPPORT TO WORKERS

Germany's labor market reforms in the 1990s helped raise its share of the working-age population in employment by **10** percentage points

Job losses cause economic stress, as well as physical, emotional, and psychological distress. A wide body of academic research has found correlations between extended unemployment and declines in physical and mental health. Studies have even shown poorer academic outcomes among the children of the long-term unemployed.[141] Other research has documented the stagnation in market incomes, and increasing wage polarization, in many developed markets.[142] Both policy makers and business leaders have a role to play in supporting workers as they transition between jobs to avoid long-term negative consequences and to ensure that they receive adequate incomes.

Actively supporting workers in job transitions

A range of measures can speed the transition of workers between jobs, beyond improving labor market dynamism, job matching, and retraining and skill development. Most countries have labor agencies focused on providing assistance to the unemployed. In many, the focus is mainly on doling out benefits and reducing fraud. Germany provides an example of a nation that overhauled its labor force system—and reduced high unemployment as a result. In 2003, when the country was still struggling with the legacy of reunification, it adopted the "Hartz reforms," based on recommendations of a labor market commission. The lower-wage segment of the labor market was liberalized, and a new category of jobs was created with employers paying a low flat rate for employees, who work a limited number of hours per week, exempt from social security and tax contributions.

The move created millions of "mini-jobs," whose wages were then supplemented by welfare payments. In addition, the local labor market agencies were restructured. Case workers are assigned to every unemployed individual, with strong incentives to successfully place their clients into jobs. Skills assessments are performed, and training is provided if needed. These reforms helped reduce the unemployment rate from 10 percent in 2003 to below 4 percent today and, at the same time, increased Germany's share of the working-age population in employment by 10 percentage points. While these reforms have returned more individuals to work, there is controversy over the impact on the post-unemployment earnings of workers.[143]

To ensure that workers develop the skills needed for the working world of the future, the German labor agency is now planning to put a greater emphasis on counseling. It is currently piloting innovative online and offline counseling services directed at students, the unemployed, but also employees in jobs which are massively impacted by digitization. The hope is that better individual orientation about job market trends and future opportunities will smooth the transition to a digital economy, without a large net loss of jobs and corresponding increase in unemployment.

[140] Matthew Taylor, *Good work: The Taylor review of modern working practices*, Report for the UK government, July 2017.

[141] Many of these studies are summarized in Austin Nichols, Josh Mitchell, and Stephan Lindner, *Consequences of long-term unemployment*, Urban Institute, July 2013; and in Edward Alden, *Failure to adjust: How Americans got left behind in the global economy*, Rowman and Littlefield, October 2016.

[142] Ibid. *Poorer than their parents?* McKinsey Global Institute, July 2016; David Autor, David Dorn, and Gordon H. Hanson, *The China shock*, January 2016.

[143] Niklas Engbom, Enrica Detragiache, and Faezeh Raei, *The German labor market reforms and post-unemployment earnings*, IMF Working Paper number 15/162, July 2015.

In Denmark, employers and governments work with unions to maintain the country's "flexicurity system," which combines active labor market policies with flexible rules for hiring and firing and high levels of benefits for unemployed individuals (up to 90 percent for the lowest paid workers). They also offer active job counseling, including career guidance, training or education to all unemployed individuals, and offer all workers access to numerous vocational training programs. This creates a labor market environment of flexible employment and job security. Notably, firms and unions get together to identify skills needs, agree on wages and enshrine rights to paid leave for training. Some studies suggest that similar collaborative efforts between employers and unions can play an important role in raising skill levels, including in the United States, and are already doing so in some cases.[144]

Neighboring Sweden has a system for retraining midcareer workers through private sector "job-security councils." Employers pay into these councils, which provide financial support and job counseling to laid-off workers, with the aim of helping them get back to work as soon as possible. Personal counselors help workers with their resumes and steer them into classes in their fields or other fields.[145]

Supporting worker incomes may also be necessary

Our research indicates that millions of individuals will likely need to transition to new occupations—and identifies the risk that wages may become stagnant or even decline for middle and lower-skill occupations that have a large supply of potential workers but might have reduced demand, particularly in developed economies. Supporting incomes in both cases may have an economic rationale. Consider that in 1914, Henry Ford announced that he would begin paying his employees $5 per day, more than twice the average wage for automakers, and reduce the work day from nine hours to eight, at a time when the 60-hour work week was the standard in American manufacturing. He explained that "unless an industry can so manage itself as to keep wages high and prices low, it destroys itself, for otherwise it limits the number of its customers. One's own employees ought to be one's own best customers."[146]

Two forms of income support need consideration in the age of automation. First are payments such as unemployment insurance to provide income to workers during training or transitioning between jobs. Yet unfortunately, the amount of public resources devoted to supporting worker transitions—including on unemployment benefits—has been declining in most countries (Exhibit 32). Given the large workforce transitions we see in the decades ahead, re-evaluating this trend could be necessary.

[144] For example, Kaiser Permanente offers programs in nursing, health-technician training, and basic language, math, and communications skills. Thomas A. Kochan, David Finegold, and Paul Osterman, "Who can fix the 'middle-skills' gap?" *Harvard Business Review*, December 2012.

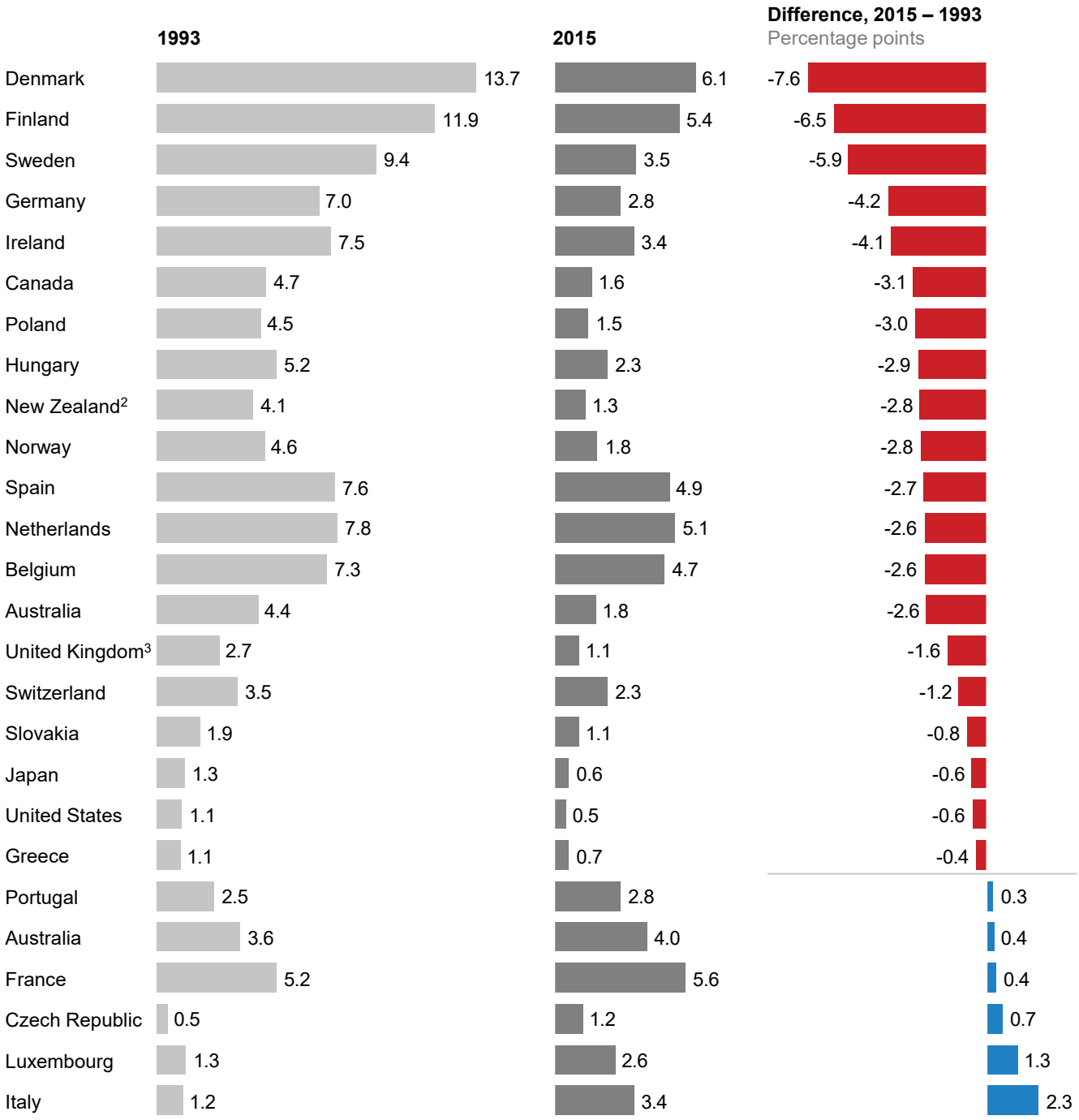
[145] Alana Semuels, "What if getting laid off wasn't something to be afraid of?" *The Atlantic*, October 25, 2017.

[146] Henry Ford, *Today and tomorrow*, 1926.

Exhibit 32

Most OECD countries have been spending less in labor markets over the past 20+ years

Total public spending on labor markets, 1993–2015[1]
% of GDP



1 Public spending on employment incentives; startup incentives; direct job creation; out-of-work income maintenance and support; early retirement; public employment services and administration; and sheltered and supported employment and rehabilitation (excluding worker training).
2 2014 data used for New Zealand.
3 2011 data used for United Kingdom.

SOURCE: OECD; McKinsey Global Institute analysis

In addition, however, wages may be under pressure in a wide range of jobs as economies transition to new forms of work. A range of options exists for addressing these income effects. Some employers can choose to pay higher wages and better benefits, recognizing the value that their workers are producing. In addition to societal responsibility, these companies may be motivated by competition for talent and an interest in reducing employee turnover. In the United States some companies have unilaterally raised minimum wages they pay.[147] In Europe, companies have traditionally paid more attention to stakeholders such as workers, in part because of unionization and regulatory choices; in Germany, for example, worker representatives sit on corporate boards under 1976 "codetermination" legislation and play an important role in shaping wage and benefit policies, as well as overall corporate strategy. There are also policy options for providing income support to workers to ensure that they remain active consumers. Minimum wages are widely deployed throughout the world, and there are moves to raise them, including in US cities such as Seattle.[148] While some studies have shown that increasing minimum wages can raise employment, the issue is actively debated. Other forms of income support, such as "earned income tax credits" and wage subsidies, provide incentives for people to work. These measures attempt to provide income support without discouraging people from working. Pilot projects are underway in a number of countries to test the idea of paying a universal basic income (see Box 9, "Experimenting with universal basic income").

In recent decades, the long-standing correlation between rising productivity and wage growth has broken down in some countries, such as the United States. The cause of this shift is unclear. But policy makers are considering new ways to ensure that wages are linked to rising productivity, so that prosperity is shared with all. Some have suggested that minimum wages should be indexed to measures of productivity. In another specific example, Singapore has a program that supports corporate investments in productivity on condition companies share the gains from productivity improvements with low-wage workers.[149] Between 2010, when the program was launched, and 2013, more than 800 projects were launched, most of them by small and medium-sized enterprises, which will benefit 53,000 workers once completed. Their wage increases are more than 10 percentage points above the national average.

•••

In the new era of automation, governments and businesses will need to undertake a balancing act between embracing the technology, which will boost productivity and economic growth, and at the same time addressing the complex transitions it will create. Ensuring robust demand growth and economic dynamism is a priority: history shows that economies that are not expanding do not generate job growth. Upgrading workforce skills and creating opportunities for midcareer job retraining will also be essential, at a time when spending on these has been declining in most countries, and labor markets will need to become more dynamic and adaptable to changing work needs and patterns of worker redeployment. A final priority is reassessing and strengthening transition and income support for workers caught in the cross-currents of automation. Each of these priorities on its own presents a challenge, and all together may require a Marshall Plan-like initiative, involving clear focus and investment. In the concluding chapter, we examine the implications for policy makers, business leaders, and individual workers.

[147] Becky Yerak, "Allstate raises minimum pay to $15 an hour," *Chicago Tribune*, May 16, 2016; Tim Worstall, "Walmart to speed worker pay rises—another sign of a tight labor market in US," *Forbes*, January 29, 2017; Danielle Paquette, "'Look, I can quit': Why Target is giving workers a big raise," *The Washington Post Wonkblog*, September 26, 2017.

[148] Noam Scheiber, "How a rising minimum wage affects jobs in Seattle," *The New York Times*, June 26, 2017.

[149] Singapore NTUC e2i (National Trades Union Congress' Employment and Employability Institute).

Box 9. Experimenting with universal basic income

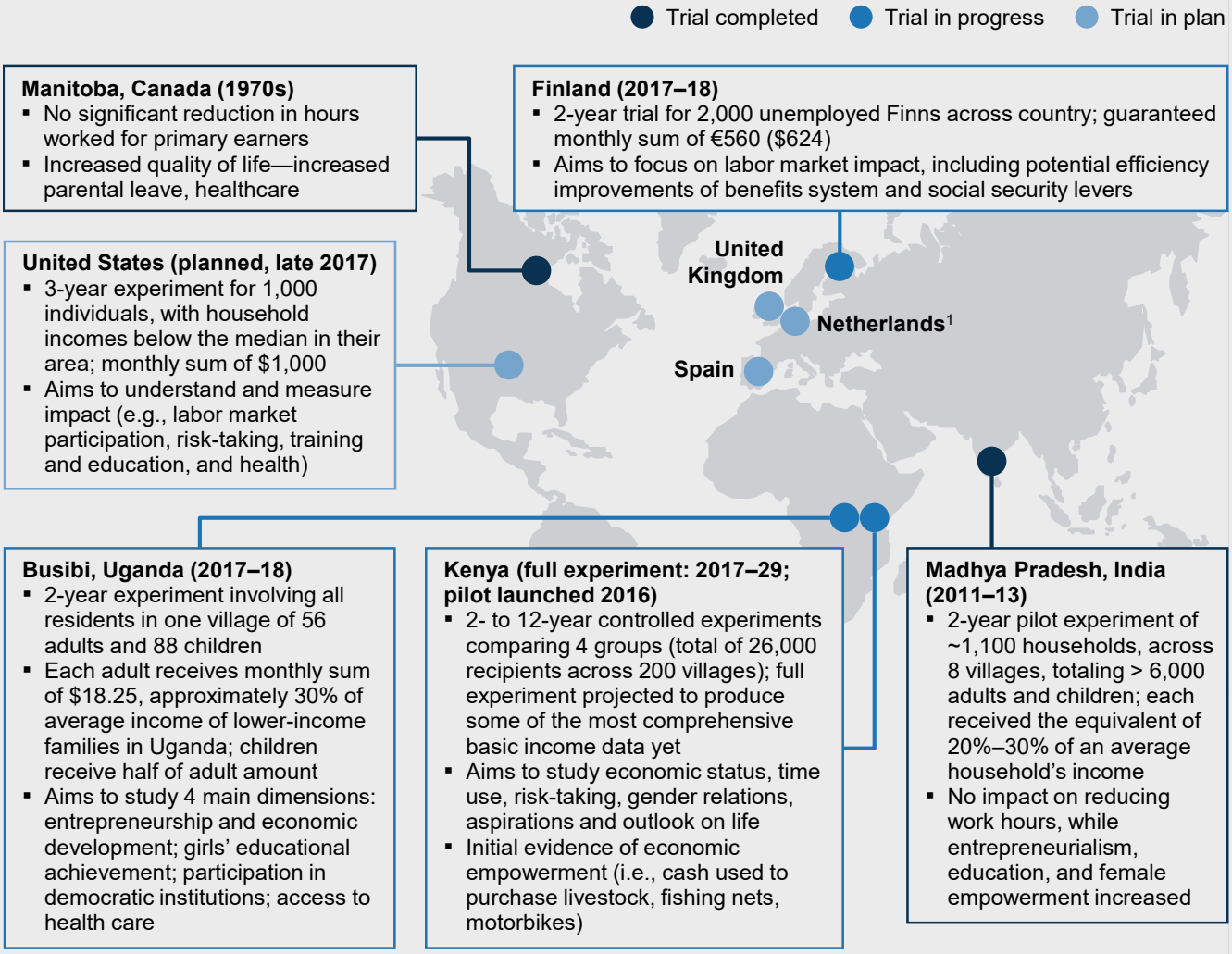
Universal basic income (UBI) consists of giving a periodic cash payment to all individuals without a means test or work requirement, to cover basic living costs. Some see it as a policy to address the challenges of a jobless future in which automation has resulted in mass unemployment.

Advocates say the assurance of a minimum standard of well-being encourages people to switch jobs and take more entrepreneurial risks, and supports consumption for those in low-paying work. Others point to the high costs and difficulties in giving cash transfers, particularly in developing countries. The potential costs are high, particularly in developed markets. An OECD study found that large tax revenue increases would be needed in most countries to finance a basic income at meaningful levels.[1] Opponents say that there is no assurance that these payments would lead to increases in innovation and that UBI could undermine productivity by discouraging work. Other arguments question the assumption of planning for mass unemployment rather than attempting to enable the mass redeployment of labor.

A number of pilots of UBI have been conducted or are now underway around the world that may shed light on the impact that this program has on incentives, work, and welfare (Exhibit 33) in developing and developed countries.

Exhibit 33

Experiments with universal basic income are being conducted in several countries


Trial completed
Trial in progress
Trial in plan
Manitoba, Canada (1970s)
No significant reduction in hours worked for primary earners
Increased quality of life—increased parental leave, healthcare
Finland (2017–18)
2-year trial for 2,000 unemployed Finns across country; guaranteed monthly sum of €560 ($624)
Aims to focus on labor market impact, including potential efficiency improvements of benefits system and social security levers
United States (planned, late 2017)
3-year experiment for 1,000 individuals, with household incomes below the median in their area; monthly sum of $1,000
Aims to understand and measure impact (e.g., labor market participation, risk-taking, training and education, and health)
United Kingdom
Netherlands1
Spain
Busibi, Uganda (2017–18)
2-year experiment involving all residents in one village of 56 adults and 88 children
Each adult receives monthly sum of $18.25, approximately 30% of average income of lower-income families in Uganda; children receive half of adult amount
Aims to study 4 main dimensions: entrepreneurship and economic development; girls' educational achievement; participation in democratic institutions; access to health care
Kenya (full experiment: 2017–29; pilot launched 2016)
2- to 12-year controlled experiments comparing 4 groups (total of 26,000 recipients across 200 villages); full experiment projected to produce some of the most comprehensive basic income data yet
Aims to study economic status, time use, risk-taking, gender relations, aspirations and outlook on life
Initial evidence of economic empowerment (i.e., cash used to purchase livestock, fishing nets, motorbikes)
Madhya Pradesh, India (2011–13)
2-year pilot experiment of ~1,100 households, across 8 villages, totaling > 6,000 adults and children; each received the equivalent of 20%–30% of an average household's income
No impact on reducing work hours, while entrepreneurialism, education, and female empowerment increased

1 Netherlands authorized testing monthly payments in 6 municipalities (Utrecht, Amsterdam pending) but not true tests of basic income. Among other basic-income defying caveats, participants are required to seek work or face removal from experiment.

SOURCE: UNICEF; GiveDirectly; Y-Combinator; KELA; McKinsey Global Institute analysis

[1] *Basic income as a policy option: Can it add up?* OECD, May 2017.

Apprentices at a car plant, Ulsan, South Korea
© Yonhap News/YNA/Newscom

6. PRIORITIES FOR GOVERNMENT, BUSINESS, AND INDIVIDUALS

Automation will be a powerful motor of future economic growth, but the challenges it presents for workforce transitions are sure to be very substantial. Policy makers, business leaders, and individual workers will need to be flexible, creative, and even visionary as they look to harness these rapidly-emerging technologies and ensure that the time of automation is a productive and prosperous one. A range of outcomes is possible, from one in which economic growth and productivity grow strongly, creating myriad new jobs, as automation is adopted rapidly, to one marked by slow automation adoption, weak economic growth and low net job growth.

Faced with the scale of worker transitions we have described, one reaction could be to try to slow the pace and scope of adoption in an attempt to preserve as much of the status quo as possible. But this would be a mistake. Although slower adoption might limit the scale of workforce transitions, it would curtail the contributions that these technologies make to business dynamism and economic growth. Automation technologies and in particular artificial intelligence are the key to finding solutions for many important societal challenges in fields ranging from climate science to health care. We should embrace these technologies, but also address the workforce transitions and challenges they bring. To do this, there are a number of imperatives and priorities for governments, business, and individuals. In this concluding chapter, we highlight a number of them.

GOVERNMENTS MUST MAKE WORKFORCE TRANSITIONS AND JOB CREATION A MORE URGENT PRIORITY

Managing the coming workforce transitions with foresight is not just a question of smart policy. Automation's power to lift the productivity of national economies has the potential to accelerate productivity and economic growth and improve lives. Governments can support the development and deployment of these technologies, for example through investments in basic and applied research, as well as through building out digital infrastructure. Ensuring positive employment outcomes will require a laser focus on retooling the workforce, stepping up support for workers in transition, and improving how local and national labor markets function. Societies can choose to transform the coming labor market disruptions into an opportunity rather than a pitfall.

As daunting as the task may seem, history shows us that governments, across the globe, when faced with monumental challenges, can rise to the occasion for the well-being of their citizens. As we have seen, the US High School Movement and GI Bill were instrumental in raising the education of the US workforce and countries such as Germany have shown that revamping labor market agencies and support for workers in transition is not only possible but can also dramatically reduce unemployment. Such examples highlight the importance of executing targeted policy decisions swiftly and clearly.

Yet in the last few decades, investments and policies to support the workforce have eroded, not been enhanced. Public spending on labor force training and support has fallen in most countries. Educational models have not fundamentally changed in 100 years; we still use systems designed for an industrial society to prepare students for a more dynamic, rapidly-changing knowledge economy. Unions are on the decline. Government data collection on the growing independent workforce and new ways of working is fragmented. It is now critical to reverse these trends. A new "Marshall Plan" for the workforce is needed. Priorities include the four areas for action discussed at length in Chapter 5, but also the following:

- **Radically scale midcareer training opportunities to make lifelong learning a reality.** Lifelong learning has long been talked about reverentially in policy circles, but the new age of automation will be the time when large-scale application of it will be needed more than ever. Flexibility and adaptability will be the new workforce mantras, as machines both replace some human activities and—probably more frequently—fundamentally change them. Recent examples of effective large-scale retraining of midcareer workers are few and far apart. For the future, more short-term and targeted training for people will be needed, especially for those in midcareer who will be looking to develop new skills even if they keep their jobs.

- **Modernize educational systems for the 21st century.** Our analysis of the performance capabilities most in demand in the new age of automation shows the critical importance of technology skills, but also of teamwork, creativity, communication, and social and emotional skills. Schools in many countries continue to adhere to a culture of education that remains rooted in 19th century notions of teaching and learning. Governments and educators can use digital technologies to change that, for example creating more individual learning paths for students. Several countries including Germany and Switzerland continue to show that apprenticeships can be a powerful and successful approach to teaching technical skills. While university education has grown in popularity and lost its elitist reputation in many countries, many tertiary educational institutions have not focused sufficiently on the needs of the labor market or of the graduates entering it. Publishing job placement of graduates and similar data could help both employers looking for recruits and potential students trying to decide on their course of study. Singapore has shown through its SkillsFuture Initiative that individuals can be supported and motivated to continuously acquire new skills. Finally, governments could encourage, identify, and co-finance innovative pilot programs that address known skills gaps among workers, post-secondary students, and youth—and then scale the ones that work.

- **Expand transition support measures for workers.** Denmark, Germany, and Sweden, among others, have shown the importance of focusing labor agencies on reemployment and the acquisition of new skills, rather than simply on handing out unemployment benefits or controlling for fraud. Best practice requires a cultural shift of sorts, one that nudges workers to take a more active role in their own retraining and provides tools for them to be successful. Mobility can be an important part of that transition process, and in the United States, at least, it was long prized. However, mobility within borders has slowed in advanced countries including the United States, and mobility across borders faces new hurdles globally as countries revisit immigration policies and practices. Reducing the barriers to mobility—which include legal ones alongside prohibitive housing costs—will need to be a policy priority. And governments should not lose sight of the cardinal importance of increasing economic mobility and opportunity for all citizens. That means universal access to quality education, good neighborhoods, and basic healthcare.

- **Create income support measures consistent with the new wage realities.** Since 1970, market wages and productivity growth have diverged in some advanced economies including the United States, and income inequality has grown. With the advent of the new automation age, it is important to begin national discussions on whether we can assume that everyone who works can support a decent standard of living. A healthy consumer class is essential for both economic growth and social stability. Income supplementation programs already exist in certain countries, such as the earned income tax credit in the United States, and some countries are testing universal basic income programs or raising minimum wages; more could follow suit, to provide fact-based findings that can inform the debate.

- **Make job creation and worker re-deployment a national priority.** A broad range of incentives exists for businesses to invest in capital and research and development. Something similar is needed to encourage investment in human capital. In addition, governments could assess the impact on job creation of their policies and investments, much as they currently assess the impact of policies on the environment. Companies could be encouraged to invest in worker training and redeployment through tax and other incentives, just as they often are for their research and development investments; in some countries, that will mean reconsidering tax codes that provide subsidies (through interest) for investments in capital while taxing labor. The step-up scenario in this report showed the value in job-creation terms of raising public—and, with it, private—investment in infrastructure, affordable housing, and energy efficiency and climate change. Such investment will need to go hand-in-hand with other backing for job creation, including supporting entrepreneurship and small business creation by streamlining regulations and revisiting personal bankruptcy laws that discourage risk-taking, for example.

- **Modernize data collection on the labor market.** Government surveys of households and employers are the gold standard of national economic data. But these are time-consuming. In today's dynamically changing world, governments need to supplement these surveys with real-time data on the adoption of automation technologies, job openings, labor market dynamism, skills in demand, and how individuals are coping with job transitions.[150] The need for better data amounts to an opportunity for government statistics agencies to collaborate with online sources of data, including job boards, professional sites such as LinkedIn, and private tech companies, to obtain a more detailed and accurate picture of jobs, skills, wages, and individual mobility and career moves.

BUSINESS LEADERS SHOULD EMBRACE AUTOMATION AND AI WHILE CAREFULLY MANAGING WORKFORCE TRANSITIONS

20%
Proportion of AI-aware C-suite executives in our survey who say their companies use AI-related technology as a core part of their business

Business leaders also have much to gain by early adoption of automation technologies, enabling performance benefits such as quality and speed, as well as greater efficiency and productive use of all factors of production. But businesses will also be on the front lines of the workplace as it changes. Successful adoption of automation will require companies to re-imagine their entire business processes to take advantage of automation's benefits, rather than mechanically attempting to automate individual activities using current processes. As part of that review, they will need to reevaluate their talent strategies and workforce needs, considering how workers can be redeployed to other jobs, and where new talent may be required. Many companies are finding that it is in their self-interest—as well as important for societal responsibility—to train and prepare workers for a new world of work. Some companies are already working with external education providers or conducting in-house training—but many more could follow suit.

- **Accelerate deployment of automation and AI.** For CEOs in all industries and countries, developing an automation and AI strategy should be a priority. So far, few firms have deployed at scale. In an MGI survey of 3,000 AI-aware C-level executives, across 10 countries and 14 sectors, only 20 percent said they use any AI related technology in a core part of their businesses. Many firms say they are uncertain of the business case or return on investment. A review of more than 160 use cases shows that AI was deployed commercially in only 12 percent of cases.[151] But companies that ignore these technologies do so at their peril: the gap in performance between early adopters

[150] Tom Mitchell and Erik Brynjolfsson, "Track how technology is transforming work," *Nature*, April 13, 2017; National Academies of Sciences, Engineering, and Medicine, *Information technology and the US workforce: Where are we and where do we go from here?* National Academies Press, 2017.

[151] *Artificial intelligence: The next digital frontier*, McKinsey Global Institute, June 2017.

of digital technologies in general and AI in particular is widening. In the MGI survey, early AI adopters have higher profit margins. Our case studies in retail, electric utilities, manufacturing, health care, and education highlight automation and AI's potential to improve forecasting and sourcing, optimize and automate operations, develop targeted marketing and pricing, and enhance the customer experience.

- **Redesign businesses processes to unlock productivity gains.** Since the IT revolution began in the 1990s it has been clear that capturing the value from new technologies requires reimagining how the business operates, rather than mechanically applying automation to the current mix of activities and processes. Capturing the full opportunities offered by automation will require companies to conduct a thorough review of business processes and workflows and assess where automation could improve performance the most. That in turn requires companies to develop or acquire the talent, discipline, and know-how to implement the sort of changes that will be needed to harness the full potential of automation.

- **Rethink organizational design.** Automation adoption is a process that will not happen overnight, and the workplace norm for years to come will be people working alongside machines. This has profound implications for the way companies and their workforce are structured and organized. Until recently, for example, powerful manufacturing robots that can lift or weld have been kept well away from humans, often in cages, because of the risk of accidents. But today's robots can work intelligently and safely alongside humans. Such machine-human and machine-machine environments will become more pervasive, and that in turn will require workflows to change. Successfully rethinking organizational design will ensure that work is not only more productive and takes advantage of the new technical possibilities available, but that it will become more meaningful and rewarding for people, as the rote aspects of their jobs are taken over by machines, freeing them to use more innate human qualities including social and emotional reasoning and personal interaction.

- **Build core digital and analytics capabilities.** Companies that successfully adopt the latest automation and AI technologies typically already have strong digital capabilities. Indeed, our analysis shows that companies that are early adopters of AI are also digital leaders. There is no shortcut to creating a strong digital base. Companies will need to build the supporting digital assets, big data and analytics capabilities to make automation and AI a success. This includes building the data ecosystem and adopting the right advanced analytic techniques and tools.[152]

- **Adapt talent strategy and manage workforce transitions.** Business leaders will need to ensure that the talent their companies require to transition to more automated operations is in place. This will involve a combination of recruiting automation-savvy professionals, as well as retraining workers to play new roles. Determining the right mix of current talent, redeployed talent, and new talent from outside the company will require careful consideration. In the new era, STEM talent and data scientists will be increasingly important—and could provide a lasting competitive advantage. But filling new technical positions is expensive and time-consuming because we have not been turning out enough skilled professionals to keep up with the demand. In the United States, for instance, data scientist shortages are already appearing.[153]

[152] See *The age of analytics*, McKinsey Global Institute, December 2016.
[153] Ibid.

- **Consider partnerships for talent development.** Some companies are turning to partnerships to develop the skills needed in their workforce and help smooth transitions. As we noted in Chapter 5, some companies have begun to establish partnerships with universities and other educational institutions to provide training and skill development in their workforces. This enables large-scale retraining, without creating the staff and overhead to manage it internally. Such partnerships may become more common as companies adopt automation at scale. In the future, as technical talent shortages increase, corporate partnership with universities and colleges may become more frequent as companies seek to develop a reliable pipeline of scarce technical talent. In other sectors, such as health care and manufacturing, there are many examples of companies partnering with local community colleges to shape and create the curricula for specific degree programs. Similar collaborations might increase the availability of data scientists and other technology-related professionals.

INDIVIDUALS MUST PREPARE FOR LIFELONG LEARNING AND EVOLVING CAREERS

Individuals will need to be prepared for a rapidly evolving future of work. Acquiring new skills that are in demand and resetting intuition about the world of work will be critical for well-being. Workers everywhere will need to reexamine traditional notions of where they work, how they work, and what talents and capabilities they bring to that work.

- **Embrace a "startup of you" mentality.** In the rapidly changing future of work, individuals will be in charge of their own destiny more than ever. The days of planning to have one employer for life are long gone. All individuals will need to adopt a more entrepreneurial approach to navigating through the world of work and managing their careers. Reid Hoffman, a co-founder of LinkedIn, calls it the "startup of you" approach.[154] Individuals will become more proficient and comfortable with navigating a more digital job search and managing their personal profiles.

- **Acquire the skills that will be in demand and embark on a journey of lifelong learning.** As machines perform a wider range and variety of tasks, individuals will need to put more focus on developing the skills that humans excel at. As we have described in this report, the activities in nearly all occupations will change, with more time spent on those activities that require social and emotional skills, team work and collaboration, creativity, and higher levels of communication and logical reasoning. Both governments and businesses have a role to play in providing individuals with better information on the skills and jobs in demand. Educators play a part as well. Secondary school students in most countries receive inadequate instruction and guidance on how to plan a career in today's workplace, and even less so for a workplace that is rapidly evolving. Ultimately it will be up to individuals themselves to think carefully about what skills will be needed and how they can demonstrate those skills to employers.

- **Prepare for a world of digital job search.** Digital platforms for matching people with jobs and assessing skills are rapidly becoming the norm for hiring.[155] Individuals will need to use these technologies if they are to be competitive in the job market. In the short term, this means putting time and care into building a personal online presence. To stand out, they will need to showcase their experience, establish expertise by joining groups or posting content, and build their professional networks. Workers could also benefit from understanding and participating in the innovations around skills-based training and credentials that could accelerate their career trajectories. Individuals without formal education credentials may be able to differentiate themselves through their online reputation via recommendations from former customers or employers.

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[154] Reid Hoffman and Ben Casnocha, *The start-up of you*, Random House, 2013.

[155] Ibid. *A labor market that works*, McKinsey Global Institute, June 2015.

- **Consider new ways of working.** Not only do most people now cycle through multiple employers throughout their careers, but many are moving beyond the traditional full-time (or part-time) job altogether. As many as 30 percent of workers in the United States and Europe earn part or most of their income through independent work—that is, freelance activities, self-employment, or through rapidly expanding digital gig or sharing platforms.[156] More than 70 percent of those individuals say that they prefer independent work and they report higher satisfaction with many aspects of their work-life than people with traditional jobs, including not only flexibility, but also opportunities for advancement, creativity and variety in their work, and even more security in their income. Roughly half of independent workers supplement their income from traditional jobs (or pensions) with these activities. In a world where wages are depressed for people without the skills in demand, independent work offers an opportunity to enhance incomes and branch out into new areas.

Ultimately, automation may force us all to reassess basic notions of work. In capitalist economies, individuals earn most of their income through applying their labor; except for the disabled, all of us are born with an endowment of labor from which to earn income, but only a privileged few are born with capital. In many decades hence, the value of this labor may be diminished if we reach a state in which machines can do a large share of the work. For workers around the world, policy makers, and business leaders—and not just social scientists who specialize in socio-economic paradigms—that should give pause for thought, and be a spur for action.

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Automation represents both hope and challenge. The global economy needs the boost to productivity and growth that it will bring, especially at a time when aging populations are acting as a drag on GDP growth. For companies, the technologies can lift productivity and profits to new heights. For society as a whole, machines can take on work that is routine, dangerous, or dirty, and may allow us all to use our intrinsically human talents more fully and enjoy more leisure. Yet even as we benefit, our societies will need to prepare for complex transitions ahead, as machines replace workers in many areas. Our research suggests that it may be time to refocus the current anxious debate about automation toward issues of demand growth, and how to manage the inevitable transitions created by automation. The task at hand is to prepare for a more automated future by emphasizing the skills that will be needed and ensuring dynamic job creation. The technology is advancing rapidly; the policy choices should not tarry.

[156] Ibid. *Independent work*, McKinsey Global Institute, October 2016.

Construction workers, Mumbai, India
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TECHNICAL APPENDIX

This appendix provides details on the methodology employed in our research in the following sections:

1. Work hours that could be automated
2. Labor demand drivers
3. Macroeconomic analysis
4. Skills and wages analysis
5. Glossary of automation technologies and techniques

1. WORK HOURS THAT COULD BE AUTOMATED

This report continues and adapts the methodology and findings of the January 2017 McKinsey Global Institute report, *A future that works: Automation, employment and productivity*. A full methodology of that work is detailed in its technical appendix; we will provide only a brief summary here and how it is applied in this report.

In that report, the technical potential for automation of the global economy and projected adoption rates are determined by an analysis of the underlying work activities for each occupation, covering 46 countries. It uses databases published by institutions including the World Bank and the US Bureau of Labor Statistics 2014 O*Net database to break down about 800 occupations into more than 2,000 activities, and determines the performance capabilities needed for each activity based on the way humans currently perform them. The report further breaks down activity into 18 capabilities and assesses their technical automation potential. This framework is informed by academic research, internal expertise, and industry experts. Our report focuses on 2016–30, and thus takes the automation adoption percentage through 2030. Much of the occupational data, at the time of original analysis, was harmonized through 2014. We adopted the simplification of referring to 2016 as the starting point of the analysis, and projecting in 2014 data (such as occupational mix) into 2016 baseline (for example, automation adoption percentages).

In this report, we use these findings to size the number of jobs that could be automated by 2030. We make an assumption that each hour of work that could be automated will result in proportional job loss, for example if 10 percent of current work activity hours in an occupation will be automated, then 10 percent of jobs in that occupation will be displaced. A priori, it is unclear if this assumption is conservative or aggressive. Based on what we have seen historically, we expect in many cases that the result of activities being automated will be a redistribution of efforts on other existing or new activities. However, it is also possible that with automation, existing work processes could be radically overhauled and reduced in complexity, reducing labor demand even further beyond automation potential of current activities. We have not modeled these countervailing effects.

$$\textit{Jobs lost} = (1 - \textit{weighted automation potential}) \times \textit{2030 labor force}$$

To calculate the work hours automated in 2030, we multiply the automation adoption percentage by the size of the labor force in 2030. By doing this, we assume that the occupation mix of the economy and the underlying work activities in each occupation in 2030 are the same as today. This is a conservative assumption, because in reality, we would expect that jobs will not be added back at the same occupation mix and that new jobs will be added in less automatable sectors.

To estimate the size of the 2030 labor force, we use population projections from the United Nations, labor force participation projections from the International Labour Organization, and the natural unemployment rate for OECD countries. For countries outside the OECD, we use the maximum unemployment rate of either 2007 or 2012 to adjust for the effects of the 2008 global financial crisis on unemployment.

2. LABOR DEMAND DRIVERS

Our work examines the labor demand created by seven catalysts. We selected these seven from a shortlist of 20 after conducting high-level sizing calculations to estimate their potential to create labor demand by 2030.

For catalysts that include a per capita metric, such as spend on automobiles or number of health-care professionals, we include population growth through 2030 based on projection from the United Nations.

We capture direct and indirect jobs that could be created from each catalyst, take into account the decline in hours worked per person, and factor in globalization of work. Our model offers a static view of the potential labor demand that could be created from the seven drivers and does not factor in supply-demand dynamics and feedback from factors such as changes in wage levels. It estimates potential labor demand; whether this potential is captured will depend on the choices and investments made by businesses, policy-makers, and workers. The scenarios we construct do not take into account any sources of labor demand outside of our seven drivers that could play an important role in determining the future of work. We do not model entirely new industries and occupations that could exist in the future, in part enabled by technology; studies have shown that on average, 0.5 percent of the workforce has been working in “new jobs” per year in the past couple of decades.[157] We do not take into account sectoral shifts in industries that are not directly related to automation, such as the rise of e-commerce in retail. We also do not model changes in work structure, such as the growth of the “gig” economy, or activities within an occupation that could change as a result of technological innovation.

[157] Ibid. Jeffrey Lin, “Technological adaptation,” May 2011.

Gross Domestic Product projections

Increased prosperity is the underlying driver of many (but not all) of the labor demand sizings. Given the static modular modeling approach that we have taken, we have taken GDP per capita growth as an input to our driver models.

We use the McKinsey Global Growth Model (GGM) projections. The GGM is a global macroeconomic model that tracks long term economic trends and generates projections under a range of scenarios. For the inputs to our labor demand modeling, we use the GGM's baseline scenario where available. For countries that the GGM does not model and for Japan and Mexico, we use projections from Oxford Economics. See Exhibit A1 for the GDP/capita projections in use.

Exhibit A1

GDP growth assumptions

		United States	Germany	Japan	China	India	Mexico
GDP per capita	**2014** ($)	50,969	44,942	46,663	6,010	1,695	9,392
	2030 ($)	62,470	57,670	54,806	14,235	3,944	11,468
	Compound annual growth rate (%)	1.3	1.6	1.0	5.5	5.4	1.3

SOURCE: Global Growth Model; Oxford Economics; McKinsey Global Institute analysis

Job multipliers

For drivers of labor demand in which we are modelling an increase in spend, we use job multipliers from input-output tables to calculate the number of jobs created through each additional dollar of spend. In many drivers based on linear regression analysis (for example, rising consumer spending), the general sizing approach for the number of jobs created incremental to 2014 levels is captured in the following formula:

$$\textit{Net new jobs} =$$

$$(\textit{2030 spend per capita} \times \textit{2030 population} \times \textit{2030 I – O multiplier})$$

$$- (\textit{2014 spend per capita} \times \textit{2014 projected population} \times \textit{2014 I – O multiplier})$$

To take into account projected increases in productivity between 2014 and 2030, we adjust 2014 job multipliers for projected productivity gains (from factors other than automation) to create a 2030 job multiplier.

For all labor drivers, we calculate indirect jobs using indirect job multipliers from McKinsey input-output tables based on source data from the World Input-Output Database, making adjustments as necessary informed by expert input.

To avoid double-counting, we remove particular indirect multipliers if they may overlap with our drivers. For example, we exclude all indirect effects in healthcare, education and construction, since we have sized these drivers independently. This may undercount job creation in these areas.

Globalization of trade

For drivers that include tradable goods and services, we use data from the International Trade Organization and IHS Global Insight to model level of imports and exports in our 46 country set. In drivers with global trade, we model both locally- and globally-driven labor demand. We keep this model of global trade constant between today and 2030, as shifts in globalization are beyond the scope of our analysis. This approach would result in an underestimation of job creation in countries whose global export shares in 2030 would be greater than today's shares, and similarly overestimation of job creation in countries whose share of global exports in 2030 would be lower than today's.

Trendline and step-up scenarios

For three of our seven drivers—infrastructure, residential and commercial buildings, energy transitions and efficiency—we model two scenarios. These are a trendline scenario, based on the observed patterns across countries that vary by factors such as GDP per capita, and a step-up scenario, which is based on further changes that could boost labor demand above the trendline scenario. For our seventh driver, the marketization of previously unpaid work, we have only modeled a step-up scenario. We describe the assumptions for these scenarios in the relevant sections below.

Catalyst 1: Rising incomes

Our rising incomes driver represents increase in consumer spending as well as overall spending on health care and education that results from increased prosperity (that is, rising GDP per capita) in countries. We have taken GDP per capita projections as an exogenous input to our modeling for all drivers related to change in spend.

For consumer spending, we use univariate regression analysis to identify spending trends by category using 2014 GDP per capita and 2014 consumption per capita data for the 46 countries in our model. While GDP per capita changes from 2014 to 2030 as the independent variable, we model change in spend by category for accommodation and food services, automobiles, clothing, financial services, food, household goods, leisure goods, leisure services, and utilities. (We exclude some categories of consumer spending to avoid double counting, such as public transport, which could overlap with our infrastructure driver). An adjustment is made across categories to cap overall consumption, to ensure that our regression analyses do not imply a major shift in consumption per capita. To do this, we scale overall consumption to a low and high scenario, based on consumption per capita projections from the GGM. We then multiply the 2014 and 2030 spend by 2014 and 2030 job multipliers, respectively. The productivity-adjusted 2030 job multiplier accounts for an increase in productivity, which drives some consumption categories to have negative job growth in countries where productivity growth outstrips demand growth, such as the agriculture sector in India. Additionally, we use indirect job multipliers to capture the demand created in other sectors that supply to these sectors.

Goods and services modeled under rising incomes are determined to be tradable or non-tradable, and the labor demand for those which are tradable is distributed according to 2014 levels of global trade.

Given the discrepancies between countries in funding models for education and health care, these drivers have been sized separately from the rest of consumer spending, despite some proportion of education and health care spending being funded directly by consumers. For both these sectors, we model the full sector, which would include that funded by consumers as well as public and private sector funding.

We see a trend towards increased numbers of jobs in education as GDP per capita rises. We model this relationship through univariate regressions on student-teacher ratios and gross enrollment rates across primary, secondary, and tertiary levels using 2014 data for all 46 countries in our model. We also capture the effect of aging populations; if there is low population growth and the population is aging, this decreases education jobs, and vice versa. The general formula we use is:

$$\left(\frac{2030\ student\ age\ population}{2030\ STR} \times 2030\ GER\right) - \left(\frac{2014\ student\ age\ population}{2014\ STR} \times 2014\ GER\right)$$

We use this to model projected education jobs in 2030, then subtract the number of jobs in 2014 to size the incremental labor demand in education. We then use indirect job multipliers to capture jobs created in other sectors that are suppliers to the education sector.

Catalyst 2: Health care: Rising incomes and aging

In addition to rising incomes increasing demand for jobs in health care, aging populations in many countries will likewise raise health-care demand. We model these effects of rising incomes and aging together to avoid double-counting the increase in healthcare jobs.

The change in the number of health-care jobs is modeled through bivariate linear regression with 2014 GDP per capita and aging (share of population over 65 in 2014) as independent variables and health-care professionals per 1000 people in 2014 as the dependent variable for all 46 countries in our model. We use this trendline to model the increase in health-care professionals as GDP per capita increases and population ages from 2014 to 2030 levels. We include all parts of the health-care delivery sector including hospital care, home care, nursing homes, and other support roles. We then use indirect job multipliers to capture jobs created in other sectors that are suppliers to the health-care sector.

Catalyst 3: Development and deployment of new technology

We identify trends between rising GDP per capita and spend on information technology. For enterprise IT spend, we find that a country's GDP is correlated with the amount spent on hardware, software, and IT services. For consumer technology spend, we consider only the hardware and software components of spend, and find that the richer the population (i.e. the higher GDP per capita) the higher spend on technology goods. We use univariate linear regression analyses to find a relationship between 2014 GDP per capita as the independent variable and each category of IT spend per capita in 2014 (including consumer and enterprise spending) as the dependent variable across all 46 countries. These categories of IT spend are then multiplied by productivity-adjusted job multipliers for 2014 and 2030 to calculate net new jobs. All data is based on historical baselines from Gartner's *Market Databook* published in the first quarter of 2017.[158] Finally, we use indirect multipliers to capture jobs created in sectors supplying to the IT sector.

[158] *Market Databook, 1Q17 Update*, Gartner, March 2017.

As the consumer technology element of rising incomes is captured within this driver, we omit it from the rising incomes driver. Likewise, since telecommunications and electric utilities are captured in the infrastructure driver, we did not consider increase in technology infrastructure spend as part of our technology definition in order to avoid double-counting. Finally, this driver assumes technology spend growth according to current trends and thus does not consider the scenarios of extraordinary technology spend that are possible in more rapid automation scenarios.

Catalyst 4: Infrastructure investment

In our trendline scenarios for infrastructure investment, we conduct univariate regression analyses with GDP per capita as the independent variable and infrastructure spend per capita as the dependent variable on 2014 cross-country data. From this, we estimate infrastructure spend in 2014 and in 2030, using GDP per capita projections. These 2014 and 2030 infrastructure spend numbers are then multiplied by 2014 and 2030 job multipliers for the construction sector, respectively, to estimate jobs in each year. 2030 job multipliers, as with other catalysts, are calculated using productivity growth as discussed below. The difference is the incremental addition of new infrastructure jobs between 2014 and 2030.

In our step-up scenario, we model a step-up in which countries have increased their infrastructure stock to a global benchmark of 70.5 percent of total GDP. This results in higher run-rate infrastructure spending in order to attain and maintain the infrastructure 70.5 percent benchmark, accounting for both GDP growth (accelerated in our step-up scenario) and depreciation. In all, this amounts to between $4 trillion and $4.5 trillion annual spending for economic infrastructure (transport, water, and power) compared with $2.1 trillion to $3 trillion in the trendline scenario. We assume annual non-automation productivity increases ranging from 1.5 percent to 4.8 percent in some emerging market countries based on historical trends (1.5 percent in China, 4.8 percent in Kenya, Nigeria, and the Philippines, and no productivity increases elsewhere). By the same method as the trendline scenario, we multiply 2014 and 2030 spend by job multipliers for the construction sector to estimate gross new jobs. Included in the ranges of our step-up scenario estimate are additional annual non-automation productivity increases in the remaining emerging market countries of 2.5 percent. This productivity adjustment would better indicate the range of possible outcomes in emerging market countries; in advanced economies, given low historical growth in productivity, we do not assume non-automation productivity will increase even in the low range of the step-up scenario. Finally, we use indirect job multipliers to capture jobs created in sectors that supply the construction sector.

Catalyst 5: Residential and commercial buildings

As with infrastructure, we have modeled two scenarios for residential and commercial buildings. For the trendline scenario, we again conduct univariate regression analyses, just as we did for infrastructure. For the step-up scenario, we model an increase of stock in structures to a US benchmark of 2.3 times that of total GDP, in line with data from the Bureau of Economic Analysis, and adjust downward for double-counting with infrastructure, inclusion of industrial structures, and spending on equipment outside of the construction sector. This amounted to $8.2 trillion to $9.8 trillion annual spending for buildings and structures (including residential, commercial and industrial structures) compared with $3.8 trillion to $5.5 trillion in the trendline scenario. As with the infrastructure catalyst, we also apply 1.5 to 4.8 percent productivity growth assumptions in select countries in the trendline scenario, and 2.5 percent annual non-automation productivity increase to remaining emerging market countries in the low range of the step-up scenario.

Catalyst 6: Energy transitions and efficiency

The energy transitions driver captures the potential job creation due to the shift in mix of electricity generation. The potential increase in jobs in electric power generation due to increase in demand for power is captured in the utilities category of consumer spending driven by rising incomes. We avoid double counting by isolating the mix shift effect in this driver. Using McKinsey modeled scenarios for gigawatt (GW) capacity in 2030, we multiply projected GW capacity by a jobs per GW multiplier across manufacturing, decommissioning, fuels, construction/installation, operations and maintenance by energy type (such as solar, coal, gas). Given the rapid and hard-to-predict changes in productivity across the renewables value chain, we model a minimum scenario in which rapid productivity growth continues, and a maximum scenario in which productivity gains plateau. To model a step-up scenario, we increase the GW capacity shift more heavily towards renewables targets that could help slow global temperature increases to two degrees Celsius above pre-industrial levels. This increased shift results in greater numbers of jobs created to change the energy generation mix by country.

We model potential spend on energy efficiency using estimates from the International Energy Agency's 2014 World energy investment outlook report. We use two scenarios that the IEA models: a "New Policies Scenario" and a "450 Scenario." In the New Policies Scenario, which is grouped with our other trendline drivers, "energy demand and supply projections reflect energy policies and measures that have been adopted as of early 2014, as well as other commitments that have been announced, but not implemented, taking a cautious view of the extent to which these may be realized."[159] For our step-up analysis, we use the IEA's 450 Scenario which "plots an emissions-reduction path for the energy sector consistent with the international goal to limit the rise to long-term average temperatures to two degrees Celsius."[160] In both scenarios, we use job multipliers to estimate the number of incremental jobs associated with the increase in spend that the IEA projects between 2014 and 2030, and use indirect multipliers to capture jobs created in other supplying sectors.

Catalyst 7: Marketization of currently unpaid work

We model the marketization of currently unpaid work solely as a step-up labor demand driver. We use local time-use surveys to understand the amount of time spent in various countries on unpaid domestic work including cooking, cleaning, childcare and elder care. We decrease the time spent on these activities in each country using a linear coefficient between the minimum and maximum values across countries. We then make assumptions around productivity gains in each activity through professionalization to estimate the potential for new labor demand creation.

3. MACROECONOMIC ANALYSIS

We used McKinsey's Global Growth Model to dynamically model the US economy. Given both the unemployment and productivity effects of automation, we use the model to determine the GDP growth needed to return the economy to full employment by 2030.

Of the automation effects modeled, we directly included four channels by which automation affects the economy: unemployment displacement, capital investment, total factor productivity growth, and reemployment rate. Three of the four channels are outputs from the MGI automation model. We take the unemployment displacement as the midpoint displacement directly from the automation model; capital investment as the solution cost given in the automation model; and total factor productivity as the implied productivity growth from automation that would at the minimum result in constant total output.

[159] World energy investment outlook, International Energy Agency, 2014.
[160] Ibid.

Besides the outputs from the automation model, we also included a fourth channel, the reemployment rate, which describes how displacement actually translates into unemployment. Not every displaced worker will enter unemployment; some will have the skills and the opportunity to quickly transition into a new role. We define the reemployment rate as the percentage of displaced workers expected to return to work within the year; the remaining displaced workers enter unemployment.

On top of the four channels, we modeled four different labor market scenarios. Each of the four scenarios used a different reemployment rate—low, medium, high, or full reemployment—to describe conditions such as labor market flexibility, labor market slack, skills and geographic mismatch, etc. that could influence the rate at which displaced workers return to work. For the United States, we used a 25 percent reemployment rate in the low scenario, 49 percent reemployment rate in the medium scenario (the reemployment rate of displaced workers in January 2010), 66 percent in the high scenario (the reemployment rate of displaced workers in January 2016), and 100 percent reemployment in the full reemployment scenario. The modeled unemployment displacement and capital investment by country were held constant in all scenarios. For example, in the United States, the modeled unemployment displacement was 23 percent by 2030, and expected automation capital investment $145 billion by 2030. The reemployment rates for each of the labor market scenarios differed by country and were estimated from literature and adjusted for labor market flexibility factors.

The GGM first forecasts a baseline future without taking into account the effects of automation. It then uses the inputted unemployment displacement, capital investment, total factor productivity growth, and reemployment rate, and dynamically propagates these effects of automation throughout the modeled economy. The forecasted unemployment rate, GDP growth rate, and average wage rates from the GGM are to be interpreted by their deviation from the baseline state as a directional range of scenarios for several possible future states.

4. SKILLS AND WAGES ANALYSES

In this analysis, we look at the net impact of (i) automation and (ii) labor demand creation at an occupation level, to understand which occupations could see high levels of demand vs. decline by 2030.

Baseline for skills and wages analyses

The baseline for our skills and wages analyses is the 2014 employment levels by occupation, adjusted for the effects of automation and our labor demand drivers. Elements of the economy in which we have not sized growth (such as defense) remain at 2014 levels of employment; new occupations that do not currently exist do not show in this baseline.

Mapping new labor demand and automation to jobs

Our automation modeling is mapped to each of the 820 occupation codes used by the US Bureau of Labor Statistics for all of the 46 countries in our model. We multiply the percentage automation adoption rate in 2030 for each occupation by the size of each occupation in 2030 (which is assumed to be the same percentage of labor force as in 2014). This provides us with a projection of how the employment levels in jobs will be affected by automation in 2030.

To model the countervailing effect on labor demand creation, we map our drivers of demand according to a list of associated occupations on a driver-by-driver basis. Most drivers map to a specific sector, in which case we allocate incremental new jobs according to today's mix of jobs within a specified sector. In drivers that affect a narrower range of jobs, we create more customized mappings to reflect reality. For example, for energy transitions and efficiency, we map potential labor demand increase to the US Bureau of Labor Statistics' categorizations of "green jobs" and to the relevant jobs in fuels. Based on the sector of each direct job added, additional indirect jobs are created based on the specified job multipliers for a country. Indirect jobs are created according to the mix of their sector.

Combining these two calculations, we compare the total jobs displaced by automation based on our 2030 baseline (today's occupation mix, scaled in proportion with the growth of labor force) to the jobs added by our drivers to 2030. To calculate a percentage growth or decline, we divide this net change by today's employment level for the occupation.

Skills and educational categorizations

Our analyses take training requirements for jobs as a proxy for skill requirements. The five educational categories used in our analyses are: less than secondary, secondary, associate degree, bachelor's degree and advanced degree. These classifications map to the five job-zones defined by the US Bureau of Labor Statistics' O*Net and take into account educational degrees, amount of training required, and years of experience necessary in order to qualify for a given job. Associate degrees are more common in the United States than in the rest of the world and usually require two years of study.

To optimize for consistency across our modeling and data quality, we use these educational requirements from the O*Net classification across all 46 countries. This simplifying assumption is limiting in cases in which there are discrepancies among countries, but we find that requirements are broadly similar: the educational requirement to be a doctor is typically an advanced degree in most countries.

Wage assumptions

In our analyses on the effects of automation and new labor demand on wages, we keep wages constant at 2014 levels; chemical engineers, economists and lawyers were in the highest decile of wage earners in 2014 in the United States, where they remain for our analyses in 2030.

In reality, we would expect wages to adjust to shifts in response to automation and new labor demand. There could also be additional economic effects on wages, such as Baumol's cost disease, or policy effects such as minimum wage legislation. Modeling these effects on wages is beyond the scope of our analysis, so we exclude them in favor of keeping wages constant at 2014 levels. While we thus cannot say anything definitive about wage shifts and are limited in any commentary on inequality, our approach allows us to identify relative shifts between high-wage and low-wage occupations.

Exhibit A2

Glossary of automation technologies and techniques

OCTOBER 2017

This list is not comprehensive but is meant to illustrate some of the technologies and techniques that are being developed to enable automation of different work activities

Technologies and techniques		Description/examples
Artificial intelligence		Field of computer science specializing in developing systems that exhibit "intelligence." Often abbreviated as AI, the term was coined by John McCarthy at the Dartmouth Conference in 1956, the first conference devoted to this topic
	Machine learning	Subfield of artificial intelligence developing systems that "learn," i.e., practitioners "train" these systems rather than "programming" them
	Supervised learning	Machine learning techniques that train a system to respond appropriately to stimuli by providing a training set of sample input and desired output pairs. Supervised learning has been used for email spam detection by training systems on a large number of emails, each of which has been manually labeled as either being spam or not
	Transfer learning	Subfield of machine learning developing systems that store knowledge gained while solving one problem and applying it to a different but related problem. Often used when the training set for one problem is small, but the training data for a related problem is plentiful, e.g., repurposing a deep learning system trained on a large non-medical image data set to recognize tumors in radiology scans
	Reinforce-ment learning	Subfield of machine learning developing systems that are trained by receiving virtual "rewards" or "punishments" for behaviors rather than supervised learning on correct input-output pairs. In February 2015, DeepMind described a reinforcement learning system that learned how to play a variety of Atari computer games. In March 2016, DeepMind's AlphaGo system defeated the world champion in the game of Go
	Cognitive computing	Synonym for artificial intelligence
Neural networks	**Artificial neural network**	AI systems based on simulating connected "neural units," loosely modeling the way that neurons interact in the brain. Computational models inspired by neural connections have been studied since the 1940s
	Deep learning	Use of neural networks that have many layers ("deep") of a large number (millions) of artificial neurons. Prior to deep learning, artificial neural networks often only had three layers and dozens of neurons; deep learning networks often have seven to ten or more layers. The term was first used in 2000
	Convolution-al neural network	Artificial neural networks in which the connections between neural layers are inspired by the organization of the animal visual cortex, the portion of the brain that processes images, well suited for perceptual tasks. In 2012, the only entry using a convolutional neural network achieved an 84% correct score in the ImageNet visual recognition contest, vs. a winning score of 75% the year prior. Since then, convolutional neural networks have won all subsequent ImageNet contests, exceeding human performance in 2015, above 90%
	Recurrent neural network	Artificial neural networks whose connections between neurons include loops, well-suited for processing sequences of inputs. In November 2016, Oxford University researchers reported that a system based on recurrent neural networks (and convolutional neural networks) had achieved 95% accuracy in reading lips, outperforming experienced human lip readers, who tested at 52% accuracy.

SOURCE: John McCarthy et al., "A proposal for the Dartmouth summer research project on artificial intelligence, August 31, 1955," *AI Magazine*, volume 27, number 4, 2016; Hayit Greenspan, Bram van Ginneken, and Ronald M. Summers, "Deep learning in medical imaging: Overview and future promise of an exciting new technique," *IEEE Transactions on Medical Imaging*, volume 35, number 5, May 2016; Volodymyr Mnih, "Human-level control through deep reinforcement learning," *Nature*, February 25, 2015; Igor Aizenberg, Naum N. Aizenberg, and Joos P.L. Vandewalle, *Multi-valued and universal binary neurons: Theory, learning and applications*, Springer Science & Business Media, 2000; www.image-net.org; Yannis M. Assael et al., "LipNet: End-to-end sentence-level lipreading," University of Oxford (forthcoming); McKinsey Global Institute analysis

Exhibit A2

Glossary of automation technologies and techniques (continued)

OCTOBER 2017

This list is not comprehensive but is meant to illustrate some of the technologies and techniques that are being developed to enable automation of different work activities

Technologies and techniques	Description/examples	
Robotics	**Soft robotics**	Non-rigid robots constructed with soft and deformable materials that can manipulate items of varying size, shape and weight with a single device. Soft Robotics Inc. grippers can adaptively pick up soft foods (e.g., baked goods, tomatoes) without damaging them.
	Swarm robotics	Coordinated multi-robot systems, often involving large numbers of mostly physical robots
	Tactile/touch robotics	Robotic body parts (often biologically inspired hands) with capability to sense, touch, exhibit dexterity, and perform variety of tasks
	Serpentine robots	Serpentine looking robots with many internal degrees of freedom to thread through tightly packed spaces
	Humanoid robots	Robots physically similar to human beings (often bi-pedal) that integrate variety of AI and robotics technologies and are capable of performing variety of human tasks (including movement across terrains, object recognition, speech, emotion sensing, etc.). Aldebaran Robotics and Softbank's humanoid Pepper robot is being used to provide customer service in more than 140 Softbank Mobile stores in Japan
Automation product categories	**Autonomous cars and trucks**	Wheeled vehicles capable of operating without a human driver. In July 2016, Tesla reported that its cars had driven over 130 million miles while on "Autopilot." In December 2016, Rio Tinto had a fleet of 73 driverless trucks hauling iron ore 24 hours/day in mines in Western Australia
	Unmanned aerial vehicles	Flying vehicles capable of operating without a human pilot. The unarmed General Atomics Predator XP UAV, with roughly half the wingspan of a Boeing 737, can fly autonomously for up to 35 hours from take-off to landing
	Chatbots	AI systems designed to simulate conversation with human users, particularly those integrated into messaging apps. In December 2015, the General Services Administration of the US government described how it uses a chatbot named Mrs. Landingham (a character from the television show *The West Wing*) to help onboard new employees
	Robotic process automation	Class of software "robots" that replicates the actions of a human being interacting with the user interfaces of other software systems. Enables the automation of many "back-office" (e.g., finance, human resources) workflows without requiring expensive IT integration. For example, many workflows simply require data to be transferred from one system to another

SOURCE: www.ald.softbankrobotics.com; *A tragic loss*, Tesla blog, June 30, 2016; *Resource revolution: Transformations beyond the supercycle*, McKinsey Global Institute, forthcoming in 2017; www.ga-asi.com/predator-xp; Jessie Young, *How a bot named Dolores Landingham transformed 18Fs onboarding*, www.18f.gsa.gov, December 15, 2015; McKinsey Global Institute analysis

Nurse with elderly patient, Japan
© The Welfare & Medical Care/Dex Image/Getty Images

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December 2017
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